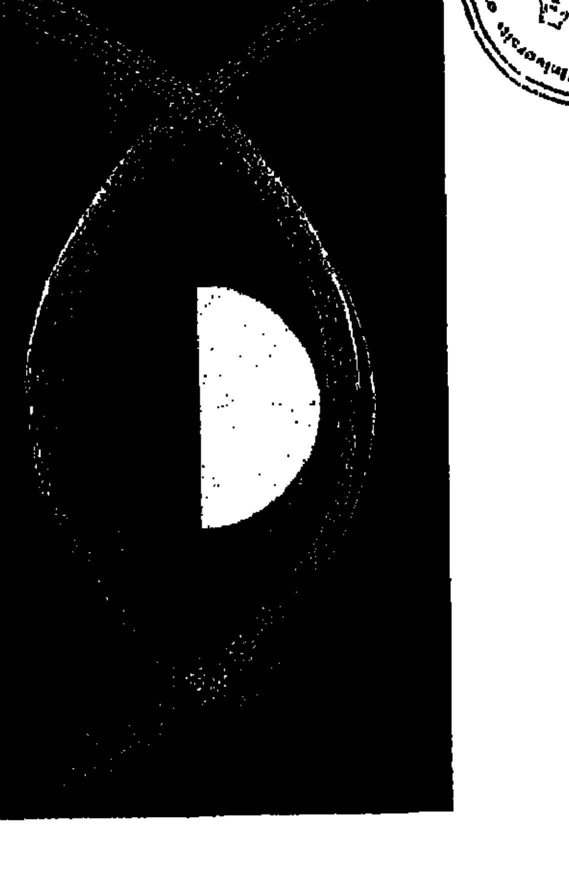
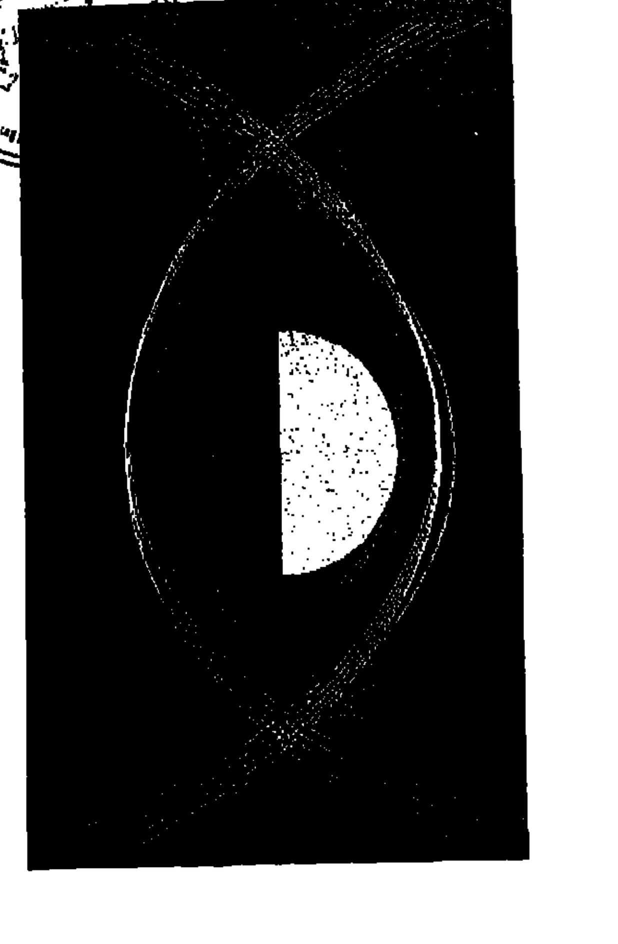
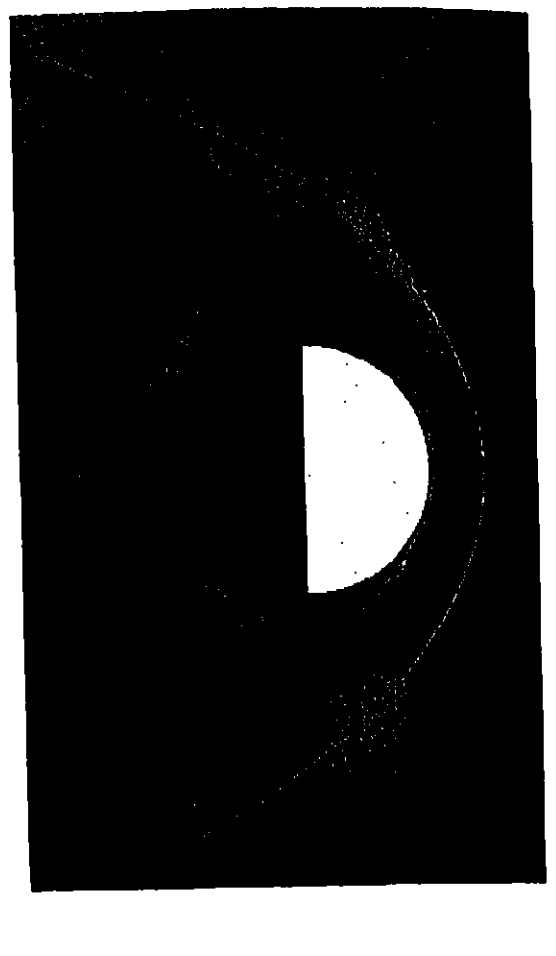






EOS
Transactions, American Geophysical Union
Vol. 65 No. 25 June 19, 1984

Eos, Transactions, American Geophysical Union Vol. 65, No. 25, Pages 401–408 June 19, 1984

Tectonophysics

8150 Plate tectonics
PREFERENTIAL RIFTING OF CONTINENTS: A SOURCE OF DISPLACED TERRANES
Gregory E. Vink (Department of Geological and Geophysical Sciences, Princeton University, Princeton, New Jersey, 08544), W. Jason Morgan and Wu-Ling Zhao

Lithospheric rifting, while prevalent in the continents, rarely occurs in oceanic regions. To explain this preferential rifting of continents we compare the total strength of different lithospheres by integrating the limits of lithospheric stress with depth. Comparisons of total strength indicate that continental lithosphere is weaker than oceanic lithosphere by about a factor of three. Also, a thickened crust can halve the total strength of normal continental lithosphere. Because the weakest area acts as a stress guide, any rifting close to an ocean-continent boundary would prefer a continental pathway. This results in the formation of small continental fragments or microplates, which once accreted back to a continent during subduction are seen as displaced terranes. In addition, the large crustal thicknesses associated with suture zones would, ironically, make such areas likely locations for future rifting episodes. This results in the tendency, described as the Wilson Cycle, of new oceans to open along the suture where a former ocean had closed. (Rifting, displaced terranes, lithospheric strength, Wilson Cycle).

J. Geophys. Res., B, Paper 4B0596

8150 Plate Tectonics
EVIDENCE FOR A HOTSPOT ORIGIN OF THE CAROLINE ISLANDS
R. B. Keating (Hawaii Institute of Geophysics, University of Hawaii, 2525 Correa Road, Honolulu, Hawaii 96822), D. P. Mattey, C. E. Helsley, J. J. Naughton, D. Epp, A. Lazarevicz, and D. Schwank

The results of paleomagnetic, geochemical, and radiometric studies of the Eastern Caroline Islands in the western Pacific indicate that the islands were formed by a hotspot located near the paleoequator between 1 and 11 m.y.b.p. The islands show a linear progression of mean ages from 1 m.y. in the east (Kusaie) to 11 m.y. in the west (Truk). The results of volumetric measurements, geochemical, and mineralogical studies suggest that the hotspot source is waning and perhaps has been slowly dying during the time Truk, Ponape, and Kusaie were being formed.

The shield-building magmas of the Caroline Islands consist of a differentiated alkalic series showing subtle geochemical differences. The post-erosional lavas are highly silica-undersaturated and trace element-enriched nephelinites. The latter were erupted subsequent to the cessation of the main shield phase of volcanism. The petrography and geochemical evolution of Truk, Ponape, and Kusaie is strongly reminiscent of that of the Hawaiian chain; however, Caroline shield-building lavas are compositionally more similar to Hawaiian alkalic lavas.

J. Geophys. Res., B, Paper 4B0691

8150 Structure of the Lithosphere
INTRAPLATE EXTENSIONAL TECTONICS OF THE EASTERN BASIN-RANGE: INFERENCES ON STRUCTURAL STYLE FROM SEISMIC REFLECTION DATA, REGIONAL TECTONICS AND THERMAL-MECHANICAL MODELS OF BRITTLE-DUCTILE DEFORMATION
R. B. Smith (Department of Geology and Geophysics, University of Utah, Salt Lake City, Utah, 84112-1183) and R. L. Bruhn

The general lack of a correlation between earthquakes and surface faulting in the interior of the western U.S. Cordillera has motivated our efforts to evaluate the geometry, structural style and mechanism of normal faulting characteristic of this region of intraplate extension. To address the problem we have interpreted over 1500 km of seismic reflection data and constructed detailed cross-sections of the upper-crust. Rheological models of the continental crust were calculated to examine the possibility of shallow, quasi-plastic flow and its influence on faulting in the eastern Basin-Range, the western Colorado Plateau and the Middle Rocky Mountains. Our data and interpretations have revealed the following styles of Cenozoic deformation: 1) steep- to low-angle dip, normal faulting along the Wasatch fault; 2) low-angle dip and listric normal faulting possibly associated with movement on pre-existing thrusts; 3) the occurrence of asymmetric, mostly eastward-tilted Tertiary basins that are bounded by low- to moderate-dipping planar and listric faults; and 4) at least three vertically-stacked, en echelon low-angle reflections in the mid- to upper-crust that dip gently westward from ~3 km beneath the Wasatch Plateau to ~15 km at the Utah-Nevada border; these reflections are interpreted as normal detachment faults. The structural style of the pervasive low- to moderate-angle dipping faults cannot be easily reconciled with classic brittle failure theory, but the interpreted termination of normal faults at or above the deeper low-angle reflections suggests the presence of shallow zones of ductile deformation that may have accommodated slip. An important observation, based on interpretations of seismic reflection profiles, is that normal fault zones dip more gently in the subsurface than their associated scarps in unconsolidated surficial deposits. Segment boundaries of the Wasatch fault zone apparently coincide with the positions of east-trending displacement transfer structures in thrust sheets and the position of the Precambrian Uinta aulacogen, suggesting that pre-existing crustal structure partly controls the geometry of extension. To examine the influence of ductile deformation, quasi-plastic flow was modeled for appropriate geotherms of the Basin-Range and Colorado Plateau crusts. These models provide constraints on the depth to the frictional/quasi-plastic transition that occurs at shallow as ~8 km in the eastern Basin-Range. This depth also corresponds approximately to the depth above which most accurately determined earthquake foci for small earthquakes (M < 5.5) occur, and suggests the presence of a low shearing strength layer in which low-angle faulting may be accommodated. Larger magnitude earthquakes (M > 5.5) appear to nucleate at 15–?? km in or near the brittle/ductile transition. The rheological modeling suggests that a thermally deforming continental lithosphere plays an important role in the evolution of this extending intraplate region. Large-scale low-angle reflections may represent decollements and normal faults at the top of upper crustal zones of reduced shearing strength and higher ductility. (Basin-Range, extensional tectonics, crustal rheology, seismic reflection data, low angle faulting, Middle Rocky Mountains, Wasatch Fault)
J. Geophys. Res., B, Paper 4B0613

R. Giovanelli 1915–1984

Ronald Gordon Giovanelli, D.Sc. F.A.A., an eminent Australian scientist in the fields of physics and astronomy, died after a long illness on January 27, 1984, at the age of 69.

After graduating from the University of Sydney, he spent 2 years (1937–1938) as a Research Fellow at the Commonwealth Solar Observatory (Mount Stromlo). It was here that he developed his life-long interest in solar optical astronomy and the theory of solar active regions.

It is perhaps unfortunate that his work in this field had to be postponed for some years while Giovanelli joined the original group of nine scientists who were recruited by CSIR (now CSIRO) to establish the Australian National Standards Laboratory. He spent 1940–1941 at the U.K. National Physical Laboratory preparing for this task. Returning to Australia in 1941 he became deeply involved in scientific support of the war effort, particularly with respect to the production of optical munitions and military problems of night vision. After the war he played an important part in establishing Australia's national standards of physical measurement in the fields of optics, photometry, and colorimetry. In 1958 he was chosen as Chief of the Division of Physics of CSIRO, a position he held until 1974, when the onset of his long illness necessitated his retirement from administrative duties.

During this period, which spanned most of Giovanelli's working life, he carried a heavy load of lecturing and training solar physicists as well as the administrative duties and contributions to scientific societies. Nevertheless he found time to pursue his main interest of optical solar astronomy and related theoretical problems of the solar atmosphere and interplanetary space. He set up modern observatories, first at Fleurs near Sydney and later at Culgoora in northern New South Wales. He was responsible for much of the unique optical equipment including the 1/20 A filter of the sophisticated magnetograph.

These developments and the related theoretical work, published in roughly 100 papers, covers a wide variety of problems including extensive studies of the diffusion of light through stellar atmospheres. However, Giovanelli had sensed, even as early as his Stromlo days, that the most interesting phenomena in the solar atmosphere are closely related to the magnetic fields extending through the solar surface. A fundamental feature of plasmas, including, of course, the solar atmosphere and its interplanetary extension, is the interplay of energy forms between the energy of magnetic fields on the one hand and the kinetic energy of particles on the other. Following earlier observational studies of solar flares and their structural relationships to sunspot magnetic fields, Giovanelli in 1946 advanced a theory that the flare optical emission is from atoms excited by electrons accelerated in induced electric fields near neutral points in the evolving magnetic fields of sunspots. This and subsequent publications in 1947 and 1948 introduced the concept that we now call magnetic reconnection (or magnetic merging or magnetic field annihilation). It is not necessary to stress the importance of this concept, which is the basic feature of modern theory of solar and stellar flares as well as a number of important phenomena in the magnetospheres of the earth and other planets.

After 1974, Giovanelli retained an affiliation with CSIRO as a Senior Research Fellow, spending much time in various observatories and other research institutes around the world. During this period his main research interest was the basic problems of the origin of the solar magnetic fields and the activity cycle. This problem has been outstanding for more than a quarter century, but for most of that time the observational data available was so limited and so inaccurate that a sound physical theory was not achievable. The so-called turbulent dynamo theory is almost entirely a mathematical edifice with most parameters simply guesswork. Giovanelli undertook a careful investigation of the properties of the concentrated tubes of magnetic flux which make up most or all solar magnetic fields. His last papers, some unpublished, were directed at a refutation of the popular theory of the origin of solar magnetic fields and the advancement of an alternative based mainly on observational data and physical arguments.

Ron Giovanelli's contributions to science and technology extended far beyond his research work. In Australia and abroad he taught and lectured extensively and served on numerous commissions and in other capacities in scientific bodies. He helped in the growth of Australia's national measurement system by serving as a member of the National Standards Commission from 1959 to 1976. In 1962 he was elected a Fellow of the Australian Academy of Science and subsequently served on the National Committees for Astronomy, Space Research, the International Quiet Sun Years, and Solar-Terrestrial Physics as well as on the International Relations Committee and Science and Industry Forum. He was largely responsible for the setting up in 1966 of the Astronomical Society of Australia and served as president from 1968 to 1971. He was active within the International Astronomical Union, serving as president of Commission 12 (Solar Radiation) from 1973 to 1976.

Ron traveled abroad frequently and made extended visits to many observatories, including those at Kitt Peak, Sacramento Peak, Arcetri, and Freiburg. Many of his happiest times were spent in Tucson and the surrounding areas in Arizona, New Mexico, Colorado, and Mexico. Apart from the frequent occasions when we were in different countries, I worked closely with Ron from 1967 to the day before he died. Ron was always accompanied by his wife Kath who was nearly as well known in the astronomical community as Ron himself. She was also well known in the art worlds of Sydney and Tucson and at one stage she interested Ron in the techniques of pottery. Some of the results are still to be found among the staff of Sacramento Peak Observatory.

During Ron's last few days a happy note was struck by the arrival of the proofs of his book *Secrets of the Sun* (Cambridge University Press), written for nonphysicists. I visited him in a hospital intensive care ward to find him elated about his book and, incredibly, giving dictation for his last publication. His death, which he knew to be imminent, occurred the next day.

This tribute was written by J. H. Piddington, *Division of Applied Physics, CSIRO, Sydney, Australia.*

News

New Climate Center

A center to direct what has been called the most broadly based scientific effort to predict the world's climate has been established at Columbia University. The goal of the new center is to predict with increasing certainty specific climate changes around the planet over periods of decades.

Formed by the Goddard Institute of Space Sciences (GISS) of the National Aeronautics and Space Administration (NASA) and the Lamont-Doherty Geological Observatory, the new Center for Climate Research was launched by a $1 million gift from the G. Unger Vetlesen Foundation.

Housed at Lamont in Palisades, N.Y., the center will draw upon the large earth-history database and preeminent geological and ocean science research work at the observatory and GISS. Scientists at the center will have at their disposal the most concentrated mass of relevant physical and observational data ever assembled for climate study, including the Lamont deep-sea sediment core library and NASA's huge array of atmospheric and satellite data.

"The Center for Climate Research will be a center of excellence in research. . .[and] will provide a more stable environment for research and education of young scientists," said Barry Raleigh, director of Lamont. "We intend the center to provide a highly visible source of the fundamental scientific work needed to support those who must make decisions in planning for the use of the world's energy, land, and agricultural resources."

"At Lamont-Doherty, ocean chemists, physical and biological oceanographers, dendrochronologists, palynologists, paleontologists, and geologists conduct research on past climates, the coupling of the oceans and the atmosphere, the effect of the oceans on mediating carbon dioxide in the atmosphere, the oceans as sinks and sources of heat, the time scales for exchange of heat and gases between the ocean and the atmosphere and a variety of related topics," Raleigh explained. "Their observations and theoretical effects provide parameters needed to improve the computer models at GISS, which in turn suggest new experiments and observations. The synergistic combination of Lamont-Doherty and GISS scientists will be the cornerstone of a major national effort in climatological research."

"We must sustain observational programs for a decade or two if the problems addressed here are to be solved, and so we will seek longer-term commitments of federal support instead of the usual 1–3 year grants currently afforded," Raleigh said.

The initial gift of $1 million has been pledged by the Vetlesen Foundation on a matching basis. Columbia University, of which the Lamont-Doherty Geological Observatory is a part, hopes to raise another $3.5 million over the next few years to assure the center of continuing activity. The effort will endow a professorial chair and provide funds for scholarships, post-doctoral fellowships, senior scholars, equipment, and operating endowment. Gifts already have been made by the Weyerhaeuser Company, SOHIO, the Exxon Research and Engineering Company, and the Exxon Education Foundation. NASA will provide financial support for post-doctoral fellowships.

CO₂ Extracts Secondary Oil

Eighty to ninety percent (or more) of the petroleum in an oil field remains in the ground after conventional primary recovery is done and the wells run dry. Secondary recovery techniques that utilize injected natural gas or water can, if successful, recover an additional 20–50% of the original oil in place, but usually most of the oil stays in the ground. In the past few years it has been discovered that injection of supercritical carbon dioxide could be effective in extracting as much as 95% of the oil in place. Major pipelines to carry carbon dioxide from natural occurrences to oil fields are now being constructed according to a recent report by F. M. Orr and J. J. Tabor (*Science, 224*, 563–569, 1984). Billions of dollars are being spent to construct three major pipelines and facilities for injecting carbon dioxide into the ground in the West Texas Permian Oil Basin.

F. M. Orr, Jr., and J. J. Tabor point out that the potential goal and the target for enhanced recovery techniques is large: "Of the more than 400 billion barrels of oil discovered in the United States, around 300 billion barrels will not be recovered by standard methods." Carbon dioxide is relatively inexpensive and effective, even after pipeline costs. Today, secondary recovery is mostly done by water or steam injection. This recovery is used in half the U. S. oil production. In the near future, carbon dioxide could account for most of the United States production.

It has been known for a long time that supercritical fluids, including carbon dioxide, are effective solvents. The mechanism in oil fields is more complex. When carbon dioxide is pumped into an oil field, viscosities, two phase regions in pseudoternary (and strictly metastable) space, and bulk oil composition (in terms of light- and heavy-molecule fractions) are important factors. Pure carbon dioxide is not miscible with crude oil. In the simplest model it is constrained by a two phase region that can be transversed to a single phase if the process of separation by differing viscosity proceeds, which it will if the crude oil has the right composition. The oil composition is not at all binary (although it is convenient to think of light and heavy hydrocarbon fractions), the system is sensitive to pressure and temperature, but the analogy seems to be consistent with field and laboratory observations. Pore pressure and other pore phenomena are important in the field, as are factors such as viscous instabilities, and the effects of water.

Orr and Tabor note that tests of the use of carbon dioxide in a range of actual oil field reservoirs have been remarkably successful, including some flooded with water. The amount of carbon dioxide needed to recover each barrel of oil was about 2000 cubic feet. The availability of carbon dioxide will thus be a limiting factor in the large-scale use of the process at present. In the future it may be economic to use the carbon dioxide that is now being vented to the atmosphere in power plant and refinery smoke stacks. Orr and Tabor state: "Despite the remaining uncertainties in the predictions of CO_2 flood performance, CO_2 supplies, and process economics, it is clear that large-scale use of supercritical CO_2 for enhanced recovery of oil is assured."—*PMB*

In Congress: Upcoming Hearings

The following hearings and markups have been tentatively scheduled for the coming weeks by the Senate and House of Representatives. Dates and times should be verified with the committee or subcommittee holding the hearing or markup; all offices on Capitol Hill may be reached by telephoning 202-224-3121. For guidelines on contacting a member of Congress, see *AGU's Guide to Legislative Information and Contacts* (*Eos*, April 17, 1984, p. 150).

June 26: Hearing on contracts by **National Oceanic and Atmospheric Administration** for mapping and charting services by the Senate Commerce, Science, and Transportation Committee and the National Ocean Policy Study. Russell Senate Office Building, Room SR-253, 10 A.M.

June 26 (tentative): Hearing on making the **Coastal Zone Management Act** (P.L. 94-370) consistent with state management plans (H.R. 4589) by the House Merchant Marine and Fisheries Committee. Longworth Building, Room 1334.

TBA: Mark up of legislation (H.R. 3200) amending the **Safe Drinking Water Act** (P.L. 93-523) by the Health and Environment Subcommittee of the House Energy and Commerce Committee. Time and room to be announced.—*BTR*

Spring Streamflow

Rapid snowmelt and heavy rains caused one of the wettest Mays on record last month, although signs of a drier season were present in a few scattered areas, according to the U.S. Geological Survey (USGS), Department of the Interior.

Reflecting overall conditions, the combined average daily flow of the nation's three major rivers was 36% above the long-term average for May, the USGS said in its regular monthly report on the nation's water resources. These rivers—the Mississippi, St. Lawrence, and Columbia—drain more than half of the 48 conterminous states, and their flows provide a useful check on the general status of U.S. water resources.

Of 172 USGS index streamflow stations surveyed in May, flows at 94 (55%) were well above average (in the upper 25% of long-term record). Streamflows at 61 stations (35%) were in the average range, while 17 stations (10%) were well below average (in the lowest 25% of long-term record).

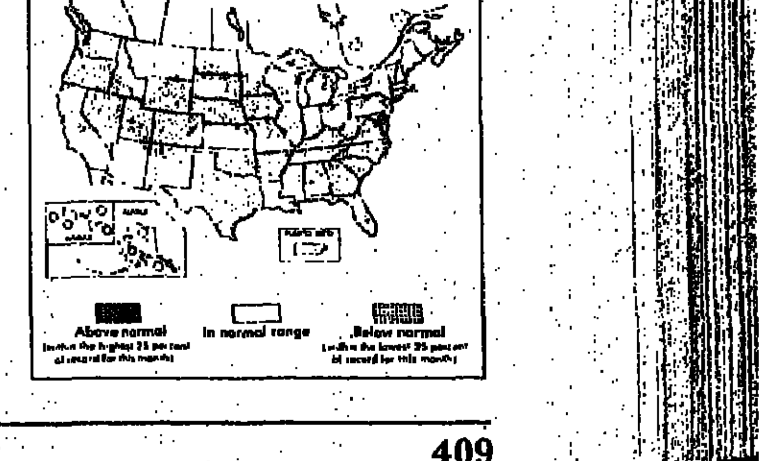
Record-high streamflows for the month of May occurred in 15 states: Colorado, Connecticut, Idaho, Iowa, Maine, New Jersey, New York, Kentucky, Nebraska, Nevada, North Carolina, Tennessee, Utah, Virginia, and Wyoming. Near-record high flows—one of the three highest flows for the period of record at each index station—occurred in eight states: Alabama, Florida, Georgia, Kansas, Mississippi, Minnesota, Oregon, and South Carolina.

Record-low or near-record-low streamflows were recorded only in Texas, Montana and Puerto Rico. At scattered points, however, streamflows declined into the well below-average range: in northern and southern California, in northern Washington and Idaho, in northern Michigan, in a small area of the lower Mississippi River Basin above New Orleans, and in Hawaii.

Floods occurred in 14 states: as a result of snowmelt in Colorado, Idaho, Oregon, Utah, Wyoming, and Nevada and as a result of heavy rains in Connecticut, Kentucky, New Jersey, New York, Oklahoma, Virginia, West Virginia, and Tennessee. Flood-related losses were greatest in Oklahoma when 12 inches of rain fell at Tulsa May 26 and 27. Flash floods occurred on two creeks in residential areas, causing 13 deaths and $250 million in damage.

Hydrologist Hai Tang at the USGS National Center in Reston, Va., said ground-water levels tended to decline seasonally toward the

News (cont. on p. 412)



The VGP News

Editor: Bruce Doe, 11721 Dry River Court, Reston, VA 22091 (telephone 703-860-3470, after 5:30 p.m.).

Amazing and Portentous Summer of 1783

C. A. Wood

The summer of the year 1783 was an amazing and portentous one, and full of horrible phenomena; for besides the alarming meteors and tremendous thunder-storms that affrighted and distressed the different counties of this kingdom, the peculiar haze, or smokey fog, that prevailed for many weeks in this island, and in every part of Europe, and even beyond its limits, was a most extraordinary appearance, unlike anything known within the memory of man. By my journal I find that I has notice this strange occurrence from June 23 to July 20 inclusive, during which period the wind varied to every quarter without making any alteration in the air. The sun, at noon, looked as blank as a clouded moon, and shed a rust-coloured ferruginous light on the ground, and floors of rooms; but was particularly lurid and blood-coloured at rising and setting. All the time the heat was so intense that butchers' meat could hardly be eaten on the day after it was killed; and the flies swarmed so in the lanes and hedges that they rendered the horses half frantic, and riding irksome. The country people began to look with a superstitious awe at the red, louring aspect of the sun; and indeed there was reason for the most enlightened person to be apprehensive; for all the while, Calabria and part of the isle of Sicily, were torn and convulsed with earthquakes; and about that juncture a volcano sprung out of the sea on the coast of Norway. On this occasion Milton's noble simile of the sun, in his first book of *Paradise Lost*, frequently occurred to my mind; and it is indeed particularly applicable, because, towards the end, it alludes to a superstitious kind of dread, with which the minds of men are always impressed by such strange and unusual phenomena.

. . .As when the sun, new risen,
Looks through the horizontal, misty air,

Shorn of his beams; or from behind the moon,
In dim eclipse, disastrous twilight sheds
On half the nations, and with fear of change
Perplexes monarchs. . . .

[*White*, 1977].

Two hundred years ago, *White* [1977], a vicar in the small village of Selborne, England, noted a peculiar haze or smokey fog that dulled the sun but intensified the summer heat. The source of the haze was unknown to White. However, the haze source was correctly inferred by his more renowned contemporary, Benjamin Franklin, as being a large eruption at Laki, Iceland. White's little known observations of the haze provide details that prompt questions concerning current models of volcano-climate interactions.

Although the eruption that caused the haze was the largest outpouring of lava in historic time, volcanologists have been slow to study it. Most of what is known comes from a preliminary report by *Thorarinsson* [1969], the late dean of Icelandic volcanologists. Thorarinsson pieced together the sequence of events from field mapping at Laki and analysis of contemporary icelandic documents describing the eruption. Following a week of earthquakes, an eruption began on June 8, 1783, near the mountain of Laki in southeast Iceland. Over the next 8 months, a 25 km line of explosion craters and fissures poured out more than 12 km³ of lava as well as prodigous volumes of CO_2 and SO_2. These gases directly led to the worst famine in Iceland's history, by stunting the growth of pasturage and resulting in the death by starvation of 50% of the island's cattle, 79% of the sheep, 76% of the horses, and 24% of the people.

It was probably H_2SO_4 aerosols from Laki that caused the haze commented on by both White and Franklin. During the summer of 1783, the haze ultimately spread to Europe, Asia, and even Africa. Similar atmospheric phenomena followed the eruptions of Tambora in 1815, Krakatau in 1883, and, to a lesser extent, El Chichón in 1982. Accounts of the effects and dispersion of such fogs are valuable because they can lead to a better understanding of atmospheric circulation patterns and volcano-induced climatic variations. There is abundant data and analyses of the Krakatau "dry fog" (summarized in *Simkin and Fiske* [1983]), some discussion of the famous "year without a summer" in 1816 following Tambora's eruption [*Stommel and Stommel*, 1983], but little mention, beyond Franklin's prescient speculation (reprinted in *Eos*, p. 601, August 10, 1982), on the origin of the fog of 1783. Thus, Gilbert White's vivid description of the atmospheric effects of the Laki eruption transcends the local history of one small English village.

White's account of the "smokey fog" of 1783 is remarkably similar to descriptions of the Krakatau and Tambora hazes. As following those better known eruptions, the sun was dimmed, becoming "blood-coloured" at sunrise and sunset. The haze was unlike any normal atmospheric fog, for it would not disperse with changing wind or weather patterns. White's comments on the rapid spoiling of butchers' meat and the profusion of flies are graphic evidence of the increased temperature. All of these observations are somewhat unexpected because the Laki eruption does not fit the current idea of how volcanic eruptions influence climate. Considerable atmospheric cooling and sunset glows following the eruption of Krakatau led to the idea that ash columns from large explosive eruptions implant immense quantities of sulphuric acid aerosols in the stratosphere. These submicron-size droplets absorb incoming solar radiation, and thus warm the stratosphere, depriving the lower atmosphere of a portion of the sun's heat. Measurements show that air temperature averages 0.2°– 0.5°C lower than the normal for 1–5 years following major eruptions [*Self et al.*, 1981], and lower temperatures have been common in North America the 2 years since the El Chichón eruption. For this process to work, the aerosols must rise into (or form in) the stratosphere; otherwise, rain would wash acid droplets out of the lower atmosphere. Thus, a cataclysmic explosion, like that of Krakatau or Tambora, is an effective mechanism to emplace volcanic ash and aerosols high in the upper atmosphere where they can be quickly dispersed by stratospheric winds over large areas of the earth, causing widespread atmospheric effects.

The Laki event does not fit this explosive pattern. The eruption was dominated by the steady effusion of lava flows, with only minor explosive activity producing a tephra deposit of 0.85 km³ [*Thorarinsson*, 1969]. The meteorologist *Lamb* [1970] inferred that the ash volume must have been 10 times larger to account for the pronounced atmospheric effects, but, actually, Thorarinsson seems to have overestimated the true volume (S. Self, personal communication, 1983). Thus, we are left to conclude (as did *Sigurdsson* [1982]) that nonexplosive eruptions of sulphur-rich lava flows may have as strong an effect on the atmosphere and climate as do cataclysmic explosive blasts. Additionally, I summized that the H_2SO_4 needed to produce the characteristic atmospheric effects associated with volcanism either does not have to be in the stratosphere or it can be injected there by less dramatic processes than explosive volcanism. The second alternative is possible, for mixing across the tropopause does occur such that the total mass of the lower stratosphere is replaced by tropospheric air every 1–2 years [*Flohn*, 1969]. Thus, some SO_2 from Laki might have entered the stratosphere by normal atmospheric mixing. For the Laki eruption, however, historic evidence implies that much of the sulphurous gases were in the troposphere. *Lamb*'s [1970] note that sulphurous smells and stinging of the eyes were reported from various parts of Europe during the period of the eruption demonstrates that there were strong concentrations of H_2SO_4 in the lower atmosphere. This observation is further evidenced by reports of plant damage in Holland in the early weeks of the eruption. Lamb doubts that the haze was in the troposphere because it was always present and was not washed out by rain. Perhaps, however, the continuing high rate of effusion (5000 m³/s [*Thorarinsson*, 1968]) at Laki replenished the haze as rapidly as it settled out of the atmosphere. Indeed, 80% of the total volume of lava (and presumably gases) spewed out during the first 50 days of the eruption [*Thorarinsson*, 1969], and the strongest atmospheric effects also occurred during the same summer months; Gilbert White observed the haze for only 1 month, coinciding with the period of strongest activity.

The eruption of Mauna Loa that began on March 25, 1984, provides a timely example of tropospheric transport of SO_2 and attendent atmospheric degradation. According to early reports (L. McClelland, Smithsonian Inst., personal communication, 1984), by April 2 a pronounced haze extended westward from Hawaii at least 5300 km to Guam, and visibility was reduced to 1.6 km at Truc and Wake islands. This extensive and dense haze was produced by degassing of less than 0.25 km³ of lava (estimated from extrusion rates). The relatively large atmospheric effect due to the small volume, short duration, and relatively low-effusion rate of the Mauna Loa eruption supports the contention that Laki and other large nonexplosive eruptions (but presumably nonstratospheric penetrating) may be climatically important.

These speculations on the mechanism by which Laki's sulphurous aerosols affected the climate are tentative; nonetheless the phenomenon did occur. If the eruption of 12 km³ of lava flows produced such noticeable atmospheric effects the relatively rapid eruption of the thousands of cubic kilometers of Columbia River basalts about 15 million years ago may have had a more profound effect. Is it possible that the colder and drier period from 14 to 12 million years ago that *Axelrod* [1981] ascribed to explosive volcanism was really a climatic result of the eruption of the Columbia River basalts? We do not know; but, clearly the Laki eruption is important for understanding at least brief climatic variations, and it may provide insight into possible long term effects. Renewed study of the Laki eruption, its products (especially the volume of the tephra layer), and its atmospheric effects are of first importance. Two hundred years after the fact is not too late to start. Gilbert White's delightful letter on the "amazing and portentous" summer of 1783 could be the first step in the geological and literary investigation of an extraordinary event.

Acknowledgments

I thank Mike Helfert and Alan Binder for reviews, Stephen Self for news on the Laki eruption,and Lindsay McClelland for real-time information on the Mauna Loa eruption.

References

Axelrod, D. I., Role of volcanism in climate and evolution, *Geol. Soc. Am. Spec. Pap., 185*, 59, 1981.
Flohn, H., *Climate and Weather*, McGraw Hill, New York, 1969.
Lamb, H. H., Volcanic dust in the atmosphere: With a chronology and assessment of its meteorological significance, *Proc. R. Soc. London, 266*, 425–533, 1970.
Self, S., M. R. Rampino, and J. J. Barbera, The possible effects of large 19th and 20th century volcanic eruptions on zonal and hemispheric surface temperatures, *J. Volcan. Geotherm. Res., 11*, 41–60, 1981.
Sigurdsson, H., Volcanic pollution and climate: The 1783 Laki eruption, *Eos Trans. AGU, 63*, 601, 1982.
Simkin, T., and R. S. Fiske, *Krakatau 1883*, Smithsonian Institute Press, Washington, D.C., 1983.
Stommel, H., and E. Stommel, *Volcanic Weather*, Seven Seas Press, Newport, R.I., 1983.
Thorarinsson, S., On the rate of lava and tephra production and the upward migration of magma in four Icelandic eruptions, *Geol. Rundsch., 57*, 705–718, 1968.
Thorarinsson, S., The Lakigigar eruption of 1783, *Bull. Volcan., 38*, 910–929, 1969.
White, G., *The Natural History of Selbourne*, Penguin, New York, 1977 (reprint of original 1788–1789 edition).

C. A. Wood *is with the NASA Johnson Space Flight Center, Houston, Texas*

Understanding Thermal Energy and Mass Transport in Major Volcanic Centers

John F. Hermance

An understanding of the thermal regimes of the earth's interior and their associated dynamic processes is of central importance, not only to basic science but to a number of national priorities including resource and the mitigation of volcanic and earthquake hazards. Major thermal anomalies over large regions of the continent are associated with intraplate rifts and transform faults (e.g., the Salton Trough and the Rio Grande Rift), distributed extensional tectonics (e.g., the Basin and Range Province), and plate margins (e.g., the Cascade Range). However, it is clear that of all classes of volcanic phenomena within the conterminous United States, the major intraplate silicic caldera complexes (e.g., Yellowstone, the Valles Caldera, the Long Valley/Mono Craters volcanic complex) appear to have, according to present estimates, the highest accessible geothermal resource base and the greatest destructive power during major eruptive phases. In addition, the exhumed fossil analogs of these systems are associated with extensive mineralization and economic ore deposits. What is lacking, however, is a predictive scientific theory describing the fundamental physio-chemical processes responsible for the development and long-term sustenance of these major volcanic centers in space and time.

Therefore, in response to a growing interest among earth scientists, geotechnologists, and government policy makers, a coordinated research effort is being mobilized by the U.S. Geological Survey (USGS), the national laboratories, industry, and universities to develop a comprehensive understanding of the morphology and dynamical evolution of these major tectono-magmatic features. Of particular interest are questions regarding the transfer of energy and mass between magma reservoirs deep seated in the crust and the shallower hydrothermal systems which they drive.

Rationale for Scientific Experiments in Intermediate and Deep Drillholes

Insight into the dynamics of these systems can be achieved by iterative use of various direct and indirect measurements to refine conceptual and mathematical models. Approaches used to date include extrapolation of surface geology, interpretation of surface geophysics, direct measurements in shallow and intermediate-depth drillholes, inferences from fluid geochemistry, and comparison with fossil magma-hydrothermal systems.

Our understanding of the total system, however, is limited by our inability to sample more than the upper and cooler parts of the active hydrothermal system itself. Although geothermal wells have been drilled to depths greater than 4 km and temperatures greater than 400°C, meaningful measurements are presently restricted to temperatures less than 250°C.

Ideally, one would like to drill and carry out observations in the entire magma-hydrothermal system, to magmatic temperatures, and to depths well within the crust. Although perhaps possible someday, at present it seems realistic to restrict our objectives to temperatures of less than 400°C and to depths of less than 4 km; in many cases this would allow one to study the "roots" of the hydrothermal systems. Direct sampling of this environment through drilling, while representing a distinct challenge to present technology, would represent a dramatic improvement in our understanding of active physio-chemical processes in this regime not obtainable in any other way.

Information from a deep drillhole to a temperature of 400°C in a magma-hydrothermal system would serve a number of purposes, only four of which are identified here.

1. A complete characterization, from top to bottom, of the natural hydrothermal system.
2. Evaluation of conceptual models for the evolution of the overall magma-hydrothermal system in space and time.
3. Quantitative parameterization of energy and mass transfer mechanisms throughout the total system.
4. Evaluation of interpretations from surface geophysical and geological observations. The drill-hole offers an opportunity to validate and to refine surface techniques in what is essentially a "calibrated" environment. This would go a long way toward optimizing predrilling exploration activities in less-studied systems elsewhere.

Background on Potential Drilling Sites

Each of the three young, large silicic volcanic complexes in the western United States (the Valles caldera, New Mexico; the Yellowstone caldera, Wyoming; and the Long Valley caldera, California) has an associated hydrothermal system and has been subjected, in some degree, to a wide variety of earth science investigations, including in some cases drilling to intermediate depths (less than 2 km). However, in none of the three areas do we have direct drill-hole knowledge of the roots of the hydrothermal systems (2–5 km) and how these hydrothermal systems derive energy from molten rock sources within the earth's crust (from depths greater than 5 km). A number of workers concur that in choosing one or more of these caldera complexes for deep drilling, the following criteria should be considered: (1) the system should represent an active counterpart of fossil caldera systems; (2) a well-defined magma body should be present; (3) the target should represent a clearly defined stage in the evolution of silicic centers; (4) a complete, compatible set of geological, geophysical, and intermediate-depth drilling data should exist; (5) a significant area of the caldera should be available to drilling in terms of both geographic accessibility and environmental sensitivity; (6) siting of the actual deep drill-hole(s) should be based on a reasonable certainty of encountering temperatures of 400°C or greater at depths of 5 km; (7) drilling and maintaining the drill-hole(s) should be technically feasible; and (8) consideration should be given to the benefits from add-on commercial drilling.

A preliminary evaluation of the three candidate caldera systems, in terms of criteria such as these, indicate that no single candidate system meets them all. On the basis of available data, the Valles caldera might appear to be reasonably favorable, primarily because of the already demonstrated high-temperature geothermal system at the Union Baca hydrothermal site, the large amount of intermediate-depth drilling by industry, and the possibility (though not certainty) of good access logistically. However, commercial drilling in the area suggests that the required hole may be extremely difficult to drill because of the underpressured nature of the formation. This situation may be encountered in the other two candidate areas as well. Such conditions may result in poor borehole stability, and the hole may be lost while drilling. Safeguarding against this exigency makes open-hole scientific experiments difficult. In turn, the need to use air or aerated drilling fluids increases corrosion and limits the ability to cool downhole equipment with the circulating fluid. It must also be recognized that massive invasion of cement into the formation during cementing operations could preclude successful perforation of the zones of interest. In addition, the presence of cement could lead to contamination of recovered samples. These problems will cause higher costs and risks for these wells than for similar wells drilled elsewhere into hydrostatically pressured formations. Some of these concerns might be mitigated by drilling outside the Union Baca hydrothermal field on Redondo dome or elsewhere in the caldera.

A recent workshop (*Eos*, June 28, 1983, p. 434) underscored the attraction of the Valles caldera as a site for continental scientific drilling since there exists a considerable background in regional and local geology, geophysics, and geochemistry. In addition, lithologic, geochemical, and thermal data have been obtained from a number of intermediate depth holes within and around the Baca geothermal field, as well as from the Hot Dry Rock project on Fenton Hill at a location immediately outside the caldera, where a hole has already been drilled to 4.5 km in basement, encountering temperatures of 325°C. To supplement these data, it has been recommended that a number of intermediate depth holes (on the order of 1 km, with one perhaps going as deep as 3 km) be drilled to better qualify (1) the magma-hydrothermaltic model, (2) features within the intrusive aureole of the principal magma chamber, (3) the stratigraphic record within the caldera structure, or (4) the possibility of interstitial melt being still present at upper levels in the crust (i.e., above 10 km).

Yellowstone clearly represents the most intense magmatic and geothermal anomaly in the conterminous United States but is an environmentally sensitive area. Even for drill-holes dedicated to purely scientific objectives, scientists and environmentalists are concerned regarding the potential hazard to geyser activity from any hydrologic disturbance. The CSDC has recently established a task group under the direction of Bob Fournier of the USGS to study these issues further and to identify unique scientific questions that can only be addressed through drilling in Yellowstone. If drilling is recommended for this area, it will, of course, be for purely scientific reasons and with full regard for mitigating any negative impact whatsoever on one of our finest national parks.

The thermal regime beneath Long Valley caldera is clearly dominated by hydrologic factors; unfortunately, however, unlike the case for the other two caldera, the hydrothermal system does not appear to have high temperatures at shallow levels. This in itself is a paradox and poses some intriguing scientific questions. Both geological and geophysical field evidence suggests the presence of a molten magma system at depths of only 8–10 km. Moreover, geochemical indicators suggest that the thermal waters, although now relatively low temperature, have derived from reservoirs where temperatures were as high as 210°-280°C.

In addition, recent tectonic deformation, seismicity patterns, and the reactivation of fumarolic activity, caused the USGS to issue, on May 25, 1982, a notice that a potential volcanic hazard exists for the southwestern segment of Long Valley caldera. If, as has been proposed, magma has intruded the upper crust of this area, surface geophysics in conjunction with borehole observations may be employed to monitor tectonic and magmatic activity associated with such a phenomenon.

An additional factor to consider in the Long Valley area is that several young volcanic systems (Inyo, Mono, and Coso), which may be in a pre-caldera stage of evolution, exist along the eastern Sierra front nearby. Studying several of these geologically related, but geographically separated, caldera systems at various stages in their evolution offers distinct advantages over concentrating studies within a single member of these silicic complexes. By restricting studies to a single system, it may be difficult to sort out various stages of geologic overprinting which occurs as these complexes evolve.

Research Needs

One of the major problems in designing a long-term drilling program and assigning drilling priorities in young silicic calderas is that the data sets on which site selections are based are not presently comparable for the three areas. Therefore, as a prelude to a deep drilling (i.e., greater than 4.0 km) at any site, a program of intermediate-depth drilling (1.0–4.0 km), needs to be carried out immediately to provide geological, geochemical, and geophysical field studies at the surface in several of the candidate areas. These investigations, along with theoretical modeling of physical processes, will enable the long-term drilling objectives to be identified more closely. Neither the scientific rationale, nor the cost effectiveness of drilling versus amount of information recovered, have been articulated in terms of specific physiochemical models for this class of system. For example, it is not completely clear what phase of the evolutionary history of a magma-hydrothermal system needs to be drilled for greatest understanding. Do we drill a young system in an early stage of development to determine the initial evolutionary conditions, or do we drill a mature system in a late stage of development? What is the basis for deciding between one hole going to great depth (10 km?) in a single system or a number of intermediate-depth holes drilled into a single system or a number of holes drilled into several systems at various stages of development? It is clear to most workers that to address these issues, geophysical and geochemical field studies, along with a program of intermediate-depth drilling (1–4.0 km), need to be intensified in these areas immediately in order to determine which of these systems have identifiable magma chambers and to characterize as closely as possible the gross features of their hydrothermal systems.

It is equally clear that the best way to achieve this is to let the science continue to evolve within the interdisciplinary, multi-institutional framework which has developed quite naturally. The role of the agencies—the National Science Foundation, the USGS, the Department of Energy, and Department of Defense—should be to minimize the artificial, though sometimes real, obstruction of good science by institutional boundaries. We should get on with the business of having scientists talk to scientists regardless of the agency which actually funds individual projects.

Acknowledgments

Many of the ideas presented here have evolved through discussions with my colleagues on the Thermal Regimes Panel of the CSDC and elsewhere. In particular I am grateful for the interaction I have had with Patrick Muffler, Bob Decker, Dick Dondanville, Hugh Taylor, John Sass, Sam Varnado, Terry Gerlach, Harry Hardee, John Colp, and Bill Luth. Although I have gleaned ideas from these and other sources, the comments presented here are not to be taken as an official position of the CSDC nor of the National Academy of Sciences.

John F. Hermance *is with the Department of Geological Sciences, Brown University, Providence, R.I.*

EOS

Transactions, American Geophysical Union

The Weekly Newspaper of Geophysics

For speediest treatment of contributions send three copies of the double-spaced manuscript to one of the editors named below and one copy to AGU.

Editor-in-Chief: A. F. Spilhaus, Jr.; **Editors:** Marcel Ackerman, Mary P. Anderson, Peter M. Bell (News), Bruce Doe, C. Stewart Gillmor (History), Clyde C. Goad, Arnold L. Gordon, Louis J. Lanzerotti, Robert A. Phinney; **Managing Editor:** Michael Schwartz; **News Writer:** Barbara T. Richman; **News Assistant:** Tony Reichhardt; **Production Staff:** Dae Sung Kim, Patricia Lichiello, Lisa Lichtenstein, Cynthia T. McManigal.

For advertising information, contact Robin E. Little, advertising coordinator, at 202-462-6903 or toll free at 800-424-2488. Advertising must be informative and consistent with the scientific and educational goals of AGU and is subject to approval by AGU. Advertisers and their agents assume liability for all content of their advertisements and for any claims arising therefrom against the publisher. Offers in advertisements are subject to all laws and are void where prohibited.

Views expressed in this publication do not necessarily reflect official positions of the American Geophysical Union unless expressly stated.

Subscription price to members is included in annual dues ($20 per year). Information on institutional subscriptions is available on request. Second-class postage paid at Washington, D. C., and at additional mailing offices. *Eos, Transactions, American Geophysical Union* (ISSN 0096–3941) is published weekly by

American Geophysical Union
2000 Florida Avenue, N.W.
Washington, DC 20009

Cover. Space shuttle photograph of an extensive SO_2 plume coming from the recent eruption of Mauna Loa volcano, Hawaii. This tropospheric plume, carried westward by tradewinds, reduced visibility to only a few kilometers at many sites in the western Pacific. This event was a small-scale version of a massive tropospheric haze that blanketed Europe in 1783 due to a prolonged eruption at Laki, Iceland. Shuttle photograph S13–37–1807. (Photo courtesy of Charles A. Wood, NASA, Johnson Space Flight Center, Houston, Texas. See article in *The VGP News* entitled "Amazing and Portentous Summer of 1783.")

News & Announcements

IAVCEI Working Group on Explosive Volcanism

The working group (W.G.) will address basic problems and unanswered questions in the realm of explosive volcanism and its products. Its primary functions are the organization of field and laboratory consortia, formal meetings, and the editing of special publications. Through these means we propose to stimulate research and communication on explosive volcanism.

The W.G. has three main areas of interest: (1) pyroclastic deposits, including characterization, stratigraphy and tephrochronology; (2) eruption mechanisms nd eruption dynamics, including geochemical and geophysical studies, modeling of volcanic systems and depositional processes, and fluid dynamics (much of this work can be applied to volcanic hazard analysis); and (3) interaction of explosive eruptions and the atmosphere.

History. Under sponsorship of the International Union for Quaternary Research (INQUA), a Commission on Tephra existed until August 1982, with the late Sigurdur Thorarinsson as Honorary President. The Commission had reached its goals of communicating the utility of tephrochronology and tephra studies to the scientific community. It supported publication of a *World Bibliography and Index of Quaternary Tephrochronology* [*Westgate and Gold*, 1974] and a meeting held in Iceland in 1980 [*Self and Sparks*, 1981].

Realization that research on explosive volcanism was rapidly expanding led the then secretary of the INQUA commission to propose that some members of the disbanded commission serve as a nucleus for a Working Group on Explosive Volcanism within the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI). A proposal for creation of a working group was submitted to the IAVCEI Secretariat at the IUGG meeting in Hamburg, August 1983. The IAVCEI Executive Committee officially approved adoption of the W.G. at the *Hamburg meeting.*

The W.G. has a rotating membership, with 25 members and 35 corresponding members. Membership will change to reflect the activities being undertaken.

Activities to date. Since formation of the W.G., it has met one of its goals in the Krakatau Symposium on Calderas and Associated Volcanic Rocks, held at the 1983 AGU Fall meeting and through publication of an upcoming special issue of JGR on the same subject.

Future events with strong participation of the W.G. include (1) a workshop on blast deposits, to be held at Mount St. Helens in August 1984 and (2) symposia, field trips, and publications on problems in phreatomagmatic volcanism, to be held at the 1986 IAVCEI meeting in New Zealand. Other topics of interest, with no specified activities at this time, include field workshops on submarine silicic volcanism, computer modeling of eruption phenomena, eruption phenomena associated with kimberlites, and the effects of explosive volcanism on agriculture, health, commerce, and energy issues.

Further ideas for field workshops, topics for study, and meetings are welcome. If you have opinions on the subject, need information on the W.G., or wish to join as a member or corresponding member, please contact either Wolfgang Elston, Secretary, Geology Department, University of New Mexico, Albuquerque, NM 87131, or Grant Heiken, W.G. leader, MS D462, Los Alamos National Laboratory, Los Alamos, NM 87545.

References

Self, S., and R. S. J. Sparks, (Eds.), *Tephra Studies*, D. Reidel, Hingham, Mass., 1981.
Westgate, J. A., and C. M. Gold, (Eds.) *World Bibliography and Index of Quaternary Tephrochronology*, University of Alberta, Edmonton, 1974.

Meetings

Volcanic Blast Workshop

A workshop on Blast Eruptions and Deposits, Mount St. Helens, Wash., will be held August 13–17, 1984. Sponsors: IAVCEI working group on Explosive Volcanism and Its Products and USGS CVO. (Michael F. Sheridan, Volcanic Blast Workshop, Department of Geology, Arizona State University, Tempe, AZ 85287 (telephone: 602-965-3760).

The major emphasis of the workshop will be to examine and discuss the products of the May 18, 1980, "blast" of Mount St. Helens and related eruptions. The topics of the technical sessions include terminology, theoretical aspects of blasts, eruptive phenomenonology, characteristics of blast deposits, and volcanic risk of blast eruptions. Following the workshop, excursions will be made to one or more of the Cascade volcanoes.

Participation in the workshop will be limited to about 50 people who have an active research commitment to the understanding of "blast" phenomena and deposits. People who would like to attend should submit a one page application letter with a statement indicating their past (or projected) research interest in "blast" phenomena or deposits. About 10–15 papers on the main topics of the workshop will be invited for presentation. Most of these papers will be collected into a volume for publication. Funding will be sought to support five or six students and an equal number of foreign scientists. All others must support their attendance through their own sources.

News *(cont. from p. 409)*

end of May. Nevertheless, levels were generally higher than long-term averages for the month.

Tang said surface-water storage was at or above average at most reservoirs. The New York City water-supply reservoirs on the Delaware River were at 100% of capacity, as were Connecticut reservoirs at Bridgeport, Hartford, Stamford, and Waterbury. In Arizona, the combined contents of Lakes Mead and Mohave were 32% above average; the Salt-Verde Reservoir System was 55% above average; and the San Carlos Reservoir measured 253% above average. In California, combined contents of 10 index reservoirs were 5% above average. In Oklahoma, contents of five of eight major lakes were above average for May.

In cooperation with nearly 800 federal, state, and local agencies, the USGS routinely gathers data on the quantity and quality of the nation's surface-water and groundwater resources at more than 45,000 stations across the country.

Following are additional details of the USGS check of the nation's water resources in May:

Five Large Rivers: Average flows of the so-called "Big Five" rivers were Columbia River at The Dalles, Ore., 228 billion gallons per day (bgd), up 30% from April and 19% below the long-term May average; Mississippi River at Vicksburg, Miss., 934 bgd, 72% above average and 10% greater than the flow in April; St. Lawrence River near Massena, N.Y., 198 bgd, a rise of 9% over April and 10% more than the monthly average; Ohio River at Louisville, Ky., 144 bgd, 69% greater than the long-term monthly average and a 25% decline from the previous month; and Missouri River at Hermann, Mo., 133 bgd, 123% above the usual May flow and down 21% from April.

Connecticut: Above-average streamflows occurred across the state, with major floods on the Connecticut and Housatonic rivers with recurrence intervals of 50–60 years (likely to occur only twice a century on the long-term average). Near historic highs were set on Burlington Brook and the Pomperaug River.

New York: Flows of all streams monitored by the USGS ranged from above average into the upper 25% of record throughout the states. Flows of many small streams were 2–3 times larger than average. Heavy rains May 28–31 caused floods responsible for four deaths and $1.5 million in damage.

Idaho: Flow of the Snake River at Weiser was in the upper 25% of normal for the 23rd consecutive month. The average daily flow of 39.6 bgd was a new high since records began at the index station in 1910. Runoff from the record snowpack caused reservoirs to fill rapidly and irrigation storage increased 11–15%, to nearly average for the month.

Utah: Floods and flood threats declined toward the end of the month. They had come about as a result of significant increases of streamflows within the well-above-average range. The seven index stations recorded streamflows 2.5 times larger than the 30-year average. The Colorado River at Cisco, Utah, reached 44.2 bgd May 27, the highest flow since 1917. The record-high average flow for the entire month was 27 bgd, which was more than 3 times greater than usual for May.

The Great Salt Lake rose more than 8 inches during the month, to an elevation of 4,208.8 feet above sea level, about 2 feet 10 inches below the recorded maximum elevation of 4,211.6 feet in 1873. Flow of the Surplus Canal at Salt Lake City reached a record-high of 2.66 bgd June 1, the highest since records began at the streamflow station 41 years ago. (Map courtesy of USGS, Reston, Va.)

Recent Ph.D.'s

Eos periodically lists information on recently accepted doctoral dissertations in the disciplines of geophysics. Faculty members are invited to submit the following information, on institution letterhead, above the signature of the faculty advisor or department chairman:

(1) the dissertation title,
(2) author's name,
(3) name of the degree-granting department and institution,
(4) faculty advisor,
(5) month and year degree was awarded.

If possible, include the current address and telephone number of the degree recipient (this information will not be published).

Dissertations with order numbers, and many of the others listed, are available from University Microfilms International, Dissertation Copies, P.O. Box 1764, Ann Arbor, MI 48106.

Noise Analysis for Conventional and Remote Reference Magnetotelluric Data, J. A. Stodt, Dep. of Geology and Geophysics, Univ. of Utah, December 1983.

Numerical Simulation of the Hillslope Runoff Processes, C. B. Burke, Sch. of Civil Eng., Purdue University, May 1983.

Numerical Studies of Mesoscale Eddies Using Quasigeostrophic and Primitive Equation Ocean Models, M. L. Batteen, Dep. of Atmosph. Sci., Ore. State Univ., June 1984.

Part I—Heat transfer, seismicity and intraplate deformation in the central Indian Ocean. Part II—the transition between the Sheba Ridge and Owen Basin: rifting of old oceanic lithosphere, C. G. Stein, Dep. of Geolo. Sci., Columbia Univ., January 1984.

Petrology and Geochemistry of Okmok and Wrangell Volcanoes, Alaska, C. J. Nye, Univ. of Calif., Santa Cruz, June 1983.

Response of Blue Glacier to a Perturbation in Ice Thickness: Theory and Observation, K. A. Echelmeyer, Seismological Lab., Div. of Geological and Planetary Sciences, Calif. Inst. of Tech., April 1983.

Rheology and microstructures of experimentally deformed quartz aggregates, P. S. Koch, Dep. of Earth and Space Sciences, Univ. of Calif., December 1983.

Seismicity and Crustal Structure Studies of Southern California: Tectonic Implications from Improved Earthquake Locations, E. J. Corbett, Seismological Lab., Div. of Geological and Planetary Sciences, Calif. Inst. of Tech., January 1984.

Silicic Volcanism at Twin Peaks, West-Central Utah: Geology and Petrology, Chemical and Physical Evolution, Oxygen and Hydrogen Isotope Studies, H. R. Crecraft, Dep. of Geolo. and Geophys., Univ. of Utah, March 1984.

Some Aspects of the Coupling between Fluid Flow and Deformation in Porous Crustal Rocks, J. S. Walder, Dep. of Geophys., Stanford Univ., April 1984.

Sorption and Sedimentation as Mechanisms of Trace Metal Removal, K. J. Farley, Dep. of Civil Eng., Mass. Inst. of Tech., June 1984.

Strain Release along Oceanic Transform Faults, L. M. Stewart, Dep. of Geolo. and Geophys., Yale Univ., December 1983.

Stress Corrosion and Crack Propagation in Sioux Quartzite, L. Peck, Dep. of Geology and Geophysics, Yale Univ., May 1982.

Structure and Evolution of the Large Scale Solar and Heliospheric Magnetic Fields, J. T. Hoeksema, Dep. of Applied Physics, Stanford Univ., April 1984.

Structure of the Himalayan Suture Zone of Pakistan Interpreted from Gravity and Magnetic Data, L. L. Malinconico, Dep. of Earth Sci., Dartmouth College, Hanover, NH., 1982.

Systematic Jointing in the Cardium Sandstone Along the Bow River, Alberta, Canada, C. Barton, Dep. of Geology and Geophysics, Yale Univ., December 1983.

Strain Release Along Oceanic Transform Faults, L. M. Stewart, Dep. of Geology and Geophysics, Yale Univ., December 1983.

Teleseismic Array Analysis of Upper Mantle Compressional Velocity Structure, M. C. Walack, Seismological Lab., Div. of Geological and Planetary Sciences, Calif. Inst. of Tech., November 1983.

The Analysis of Shallow Refraction Seismograms, P. J. Hatherly, Cent. for Geophys. Explor. Research, Macquarie Univ., Australia, May 1984.

The Consequences and Controls of Bacterial Sulfate Reduction in Marine Sediments, J. Westrich, Dep. of Geology and Geophysics, Yale Univ., May 1983.

The Dynamics of Orographic Rain with large Latent Heat Release, Yuh-Lang Lin, Dep. of Geology and Geophysics, Yale Univ., May 1984.

The Io Plasma Torus: Its Structure and Sulfur Emission Spectra, R. J. Oliversen, Phys. Dep., Univ. of Wis., September 1983.

The Marine Geochemistry of the Rare Earth Elements, H. J. W. De Baar, Mass. Inst. of Tech., February 1984.

The Relationship of Small Earthquakes to Strain Accumulation Along Major Faults in Southern California, J. C. Pechmann, Seismological Lab., Div. of Geological and Planetary Sciences, Calif. Inst. of Tech., March 1985.

The Shear Wave Velocity Structure in Northern and Central California, A. R. Levander, Dep. of Geophys., Stanford Univ., April 1984.

Trace Elements and Radionuclides in the Connecticut and Amazon River Estuary, E. P. Dion, Dep. of Geology and Geophysics, Yale Univ., December 1983.

Uplift and Cooling History of the NW Himalaya, Northern Pakistan—Evidence from Fission-Track and $^{40}Ar/^{39}Ar$ *Cooling Ages*, P. K. Zeitler, Dep. of Earth Sci., Dartmouth College, Hanover, NH, 1983.

Wastewater Injection: Near-Well Processes and Their Relationship to Clogging, J. A. Oberdorfer, Dep. of Geolo. and Geophys., Univ. of Hawaii, May 1983.

Geophysicists

B. Clark Burchfiel, professor of geology at the Massachusetts Institute of Technology, was recently elected to the American Academy of Arts and Science.

Hans M. Mark, deputy administrator at the National Aeronautics and Space Administration, will leave his post to become chancellor of the University of Texas system effective September 1, 1984. Mark became deputy administrator 3 years ago. Previously, he had been Secretary of the Air Force from July 1979 until February 1981, and Under Secretary of the Air Force from 1977. No permanent or temporary replacement has been appointed yet, according to a NASA spokesman. The president must nominate a successor, and the Senate must confirm the appointment.

In Congress: Legislative Update

For additional information on these bills, contact the sponsoring Member of Congress or committee indicated. All congressional and committee offices may be reached by telephoning 202-224-3121. For guidelines on writing to a Member of Congress, refer to *AGU's Guide to Legislative Information and Contacts* (*Eos*, April 17, 1984, p. 159). The last Legislative Update was published in the May 8 *Eos*.—*BTR*

	Senate	House
ARCTIC RESEARCH AND POLICY ACT, H.R. 2292 (Young, R-Alaska) and S. 373 (Murkowski, R-Alaska), would provide comprehensive national policy dealing with national needs and objectives in Arctic and would provide a centralized system for collection and retrieval of scientific data, establish priorities, and provide financial support for basic and applied scientific research. The House passed an amended version of the Senate bill, so S. 373 has been sent back to the Senate for approval of those House amendments before the bill is sent to President Reagan for his signature.	Passed June 27, 1983	Passed April 24, 1984
COASTAL ZONE MANAGEMENT CONSISTENCY ACT, H.R. 4589 (D'Amours, D-N.H.) and S. 2324 (Packwood, R-Oreg.), would amend the Coastal Zone Management Act of 1972 to make federal activities conducted in the coastal zone consistent, to "the maximum extent practicable," with approved state management programs. Subcommittee on Oceanography of House Merchant Marine and Fisheries Committee reported H.R. 4589 to full committee on May 3, 1984. S. 2324 was reported out of the Senate Commerce, Science, and Transportation Committee June 13, 1984.	Awaiting floor action	Awaiting committee action
EXCLUSIVE ECONOMIC ZONE IMPLEMENTATION ACT, H.R. 2061 (Breaux, D-La.) and S. 750 (Stevens, R-Alaska), would implement 200-mile EEZ adjacent to the U.S. territorial sea. Would also set forth U.S. policy on development and use of the natural resources and ocean floor. H.R. 2061 referred to House committees on Foreign Affairs, Interior and Insular Affairs, Merchant Marine and Fisheries, and Ways and Means. S. 750 referred to Senate Committee on Commerce, Science, and Transportation.	Hearings to be scheduled	Hearings to be scheduled
EXPORT ADMINISTRATION ACT AMENDMENTS, H.R. 3231 (Bonker, D-Wash.) and S. 979 (Heinz, R-Pa.), defines restrictions on the export of scientific and technical information. House passed its bill Oct. 27, 1983, and sent it to the Senate; it is on the legislative calendar there. S. 979 passed the Senate March 1, 1984, and passed the House March 8, 1984. Conferences to iron out the differences were held April 12, May 3, May 22, June 14, and June 19, 1984.	In conference	In conference
LAND REMOTE SENSING COMMERCIALIZATION ACT OF 1984, H.R. 5155 (formerly H.R. 4836) (Fuqua, D-Fla.) and S. 2292 (Gorton, R-Wash.), aims to establish a system to promote the use of land remote-sensing satellite data. Asserts that the private sector is best suited to develop land remote-sensing data markets and that cooperation between the federal government and the private sector should be initiated now to assure continuity of data and U.S. leadership in land remote sensing. A fully commercialized system should be phased in gradually, according to the bill. The Senate passed an amended version of the House bill, so H.R. 5155 has been sent back to the House for approval of those Senate amendments before the bill is sent to President Reagan for his signature. See story in upcoming *Eos*.	Passed June 8, 1984	Passed April 9, 1984
MINING AND MINERAL RESOURCES RESEARCH INSTITUTE PROGRAM, H.R. 4214 (McNulty, D-Ariz.) and S. 2186 (Warner, R-Va.), would authorize funds for the establishment of mining and mineral resources research institutes in each state. Under the aegis of the Department of the Interior, each state would plan and conduct research and demonstrations and would train mineral engineers and scientists. Passed House April 9, 1984. Senate Energy and Natural Resources ordered that the House bill override the Senate bill.	To be scheduled on Senate calendar	Passed April 9, 1984
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION ORGANIC ACT, H.R. 3381 (Forsythe, R-N.J.), would establish NOAA as an independent agency and as the agency primarily responsible for providing oceanic, coastal, and atmospheric services and supporting research (*Eos*, Sept. 6, 1983, p. 537). Would also establish procedures to avoid duplication of effort in these fields among government agencies. Referred to two subcommittees of House Merchant Marine and Fisheries Committee and one of House Committee on Science and Technology. Several other bills that would establish a Department of Trade also call for making NOAA a separate agency. Merchant Marine Committee reported the bill out of committee April 10, 1984.	No companion bill	Awaiting further committee action
NATIONAL OCEANS POLICY COMMISSION ACT OF 1983, H.R. 2853 (W. Jones, D-N.C.) and S. 1238 (Hollings, D-S.C.), would establish a 15-member commission that would develop recommendations for Congress and the President on a comprehensive national oceans policy. S. 1238 referred to Senate Commerce, Science, and Transportation Committee.	Awaiting committee action	Passed Oct. 31, 1983
PEER REVIEW REAFFIRMATION, H.Con.Res. 257 (Sensenbrenner, R-Wisc.), would reaffirm "the commitment of the Congress to award federal funds for scientific research projects and facilities solely on the basis of scientific merit as determined by a peer review process." Follows attempts by several universities to bypass peer review (*Eos*, January 3, 1984, p. 1). Referred to House Science and Technology Committee. (A concurrent resolution is used to express principles and policy.)	No companion bill	Awaiting committee action
SCIENCE AND MATHEMATICS EDUCATION, H.R. 1310 (Perkins, D-Ky.) and S. 1285 (Hatch, R-Utah). H.R. 1310 allocated $425 million for mathematics and science education in fiscal 1984 (*Eos*, March 22, 1983, p. 114). Senate bill, which also would authorize $425 million, was reported out of the Senate Labor and Human Resources Committee May 16, 1983. The Senate debated its bill on the floor on June 6, 1984, but did not complete action.	Awaiting further floor action	Passed March 2, 1984
SEVERE STORMS ADVISORY COMMITTEE ACT, H.R. 3207 (Hammerschmidt, R-Ark.), aims to assure that forecasting of severe storms within government agencies is coordinated for maximum benefit. Would establish a committee of no more than 12 members that would recommend new programs, assess current forecasting programs, and make recommendations for incorporating new technology developments into the operational forecasting system. Referred to a subcommittee of the House Science and Technology Committee.	No companion bill	Awaiting committee action
YEAR OF THE OCEAN, S.J.Res. 257 (Stevens, R-Alaska), would designate the year beginning July 1, 1984, as the Year of the Ocean (*Eos*, June 19, 1984, p. 402). Referred to the House Committee on Post Office and Civil Service.	Passed June 8, 1984	Awaiting committee action
YEAR OF WATER, S.J.Res. 202 (Armstrong, R-Ohio), would designate 1984 as the Year of Water. Aims to increase awareness and dedication to the interests of worldwide water resources (*Eos*, March 20, 1984, p. 105). Referred to House Committee on Post Office and Civil Service.	Passed Feb. 27, 1984	Awaiting committee action

Books

Role of Water in Urban Ecology

H. Hengeveld and C. De Vocht (Eds.), Elsevier, New York, 1982.

Reviewed by Neil S. Grigg

This volume is a report on a symposium on the role of water in urban ecology held in Amsterdam in August 1979. The second international environmental symposium of the Koninklijke Nederlandsche Heide Maatschappij (Royal Netherlands Land Development Society) was cosponsored by the International Association for Ecology (INTECOL) and Elsevier Scientific Publishing Company with proceedings published in a special edition of the journal *Urban Ecology*, volume 6, pp. 1–362, from which this volume is reprinted.

Although there are contributions from a fairly wide cross section of scientists interested in the topic, the editors have done an unusually good job of integrating diverse material into a comprehensive volume. Experts from a wide cross section of disciplines, geographical and language areas were asked to contribute materials on the symposium themes which were explained in advance in a short paper by the editors. During the symposium week, one comprehensive draft text was discussed rather than using individual papers. This procedure provided the opportunity from the beginning to create an integrated volume rather than a collection of disparate parts.

The volume is organized into three parts. First is an introduction to the theme of urban ecology and the influence of water. Then there are background chapters explaining the urban water aspects, the human aspects, the urban ecological aspects, water management and development, and planning in urban areas. They are followed by four chapters with case studies: one relating to the design of balancing lakes in the new town of Milton Keynes, England; a second relating to water in the new towns in the Ijsselmeerpolders of The Netherlands; a third case study of water lessons from Los Angeles; and a fourth, a carrying capacity case study in Sanibel.

The term urban ecology refers to the ecosystem viewpoint where the city is as much a biological organism as it is a physical organism. Recognizing the complexities of the physical, biological, and socio-political components of urban ecology, the organizers of the symposium sought to restrict the discussion by focusing on water. The result of the symposium (and of the volume) is summed up by the editors when they state that few parts of the document can be used as a manual and that most parts have the nature of an introductory text. The text does not give, according to the editors, new factual knowledge for the specialist, but attempts to review and interrelate information from different disciplines. In other words, it is an interdisciplinary view of a very complex set of problems. Most who have dealt with interdisciplinary efforts recognize the difficulties and shortcomings in trying to advance the state-of-the-art in any one area in a way that is scientifically satisfying. Because of this dilemma, the contributions of this volume are in the integration of subject matter rather than in advancing the state-of-the-art at the frontiers of knowledge.

The volume could be especially useful to those who seek to understand the urban ecosystem approach and the relationship with water resources. For example, the first chapter explains the interrelationships of water and human settlements and covers some of the background and development of urban ecosystem concepts.

Chapter 2 reviews the urban hydrological cycle and hydrological effects of urbanization and gives an international perspective of urban hydrology that might be seen as a literature review of the hydrological effects of urbanization from a broad point of view.

Chapter 3 covers the human aspects of urban water systems, a topic which has not been described in much detail in the engineering literature. This chapter includes a good discussion of the intangible aspects of economic analysis applied to urban water problems with a discussion of wants and needs, socio-economic thresholds, and willingness to pay and general psychological aspects of urban water utilization by humans in cities. This kind of information is very useful to managers and planners in understanding the intangible aspects of urban planning.

Chapter 4 covers nature and water in urban ecology, including a discussion of the urban ecosystem with a biotic focus and a discussion of the influence of man on this biological community. This naturally leads into quasi-agricultural subjects such as soil and water management, leading on to discussions of pollution and biota in urban areas.

Chapter 5, covering water management, is the water planning chapter where techniques for flood loss and control and other aspects of urban water engineering are covered. Like chapters 1–4, chapter 5 must be regarded as introductory in nature, providing an overview of management possibilities. This type of material will be especially useful to the reader who is not well grounded in the subject.

Chapter 6, on development and planning, will be of special interest to those who are new to the field of water planning and who desire to learn about the linkages between land planning and water planning. This chapter suffers from the same problem that plagues much of the planning literature: It is so full of charts, diagrams, and conceptual frameworks that many readers may wonder just what useful information is contained in the chapter.

Chapter 7 begins the first case study which focuses on Milton Keynes, a new town located in North Buckinghamshire, England, and the chemical and biological functions of "balancing lakes," which are generally called detention ponds in the United States. The case study of the new towns in the IJsselmeerpolders located in The Netherlands is of similar interest in that it is a view of the water management aspects of new town development including soils, environmental aspects, and hydrology. The difference, of course, is the bolder aspect of the new town development. The third case study relating to water management in California is entirely different because it addresses the problem of the super city drawing on water resources from all parts of the state to the detriment of the rural areas outside. The topic covers the history of water development for Los Angeles: the Los Angeles aqueduct system, the California State Water Project, and related political and engineering aspects. There is little discussion about the urban ecosystem aspects of Los Angeles other than the influence of the development of Los Angeles on water sources in other parts of the state. The discussion of the City of Sanibel located in southwest Florida presents an example of development on barrier islands, a difficult and complex problem all over the world, including the United States. This presentation stresses the carrying capacity approach which relates to political feasibility because of the appreciation of island residents of the sensitivity of their living environment.

Overall, the volume delivers the promises of the editors; that is, it covers introductory subjects in some detail and constitutes a good literature review but does not go into great depth in any of the topics. Some readers will especially appreciate the literature review and the wide international coverage.

Neil S. Grigg is with the Department of Civil Engineering, Colorado State University, Fort Collins, CO 80523.

The Fluid Mechanics of Astrophysics and Geophysics: Stellar And Planetary Magnetism

A. M. Soward (Ed.), vol. II, Gordon and Breach, New York, 1983, xi + 376 pp., $69.50.

Reviewed by E. N. Parker

Stellar and Planetary Magnetism represents the proceedings of the Workshop on Planetary and Stellar Magnetism held in Budapest, Hungary, August 25–29, 1980. It is the second volume in a series on the fluid mechanics of astrophysics and geophysics, edited by P. H. Roberts. The first volume is *Solar Flare Magnetohydrodynamics*, with Eric Priest as volume editor. It is clear from reading both volumes that the overall editorial policy is one of exposition for an audience much broader than the experts that contributed the papers. *Stellar and Planetary Magnetism*, like its predecessor, is as much a textbook as it is a topical review of the latest developments. The successive sections are devoted to dynamo theory, high conductivity dynamos and flux expulsion, solar magnetism, stellar magnetism, geomagnetism, and compositional convection, the last topic referring to the forces that drive the convection in the core of earth. In that respect there has been a question for years whether there is enough thermal energy released in the liquid core to drive convection and power the geomagnetic dynamo. It now appears that the slow cooling and solidification of the liquid core, to form a growing solid dendritic core at the center, is the most effective means for driving the convection. The basic thermodynamics and hydrodynamics of this effect are presented with gratifying clarity and directness.

The volume begins with a comparative review, by H. K. Moffatt, of the three main approaches to dynamo theory, followed by two chapters, by K. H. Rädler, discussing the general symmetries of the quasi-linear (first-order smoothing) approximation for the hydromagnetic dynamo equations in the context of a spherical volume. The next five chapters treat a variety of auxilliary effects that arise out of the general hydromagnetic dynamo effects, such as flux expulsion from a network of convective downdrafts, the critical Reynolds number for the onset of dynamo effects, and an unusual situation treated by S. Childress, involving intense widely separated cyclonic eddies whose mutual magnetic interactions produce an extraordinary dynamo effect when their strength exceeds a critical value.

The remaining two thirds of the book is devoted to the fluid dynamics of the convective zone of the sun and other stars and the core of earth, with specific application of the dynamo equations to the generation of the observed magnetic fields. M. Stix surveys dynamo action in late-type stars, while F. Krause reviews the classical magnetic A stars, showing that a dynamo origin of their fields is a possible and plausible alternative to the conventional view that the fields of the magnetic stars are primordial. A chapter is devoted to the possibility of dynamo action in accretion disks. There is an extensive discussion of what can be deduced about fluid motions and magnetic flux in the liquid core of earth from the observed variations of the magnetic field at the surface.

It is interesting to look back over the theoretical and observational progress of the past 40 years toward understanding the origin, and sometimes erratic behavior, of the magnetic fields of the planets, stars, and galaxies. A variety of dynamo effects have been discovered and described, and there has been a solid beginning on the dynamics of the convection within the rotating bodies that exhibit the magnetic fields. The fundamental obstacle to any "final" theories is the simple fact that only the surface of the various bodies can be observed (with the exception of the galaxy) and the fluid dynamics of their convective interiors is too complex (the Reynolds numbers are very large) a dynamical problem to permit a direct deduction of the motion from the surface characteristics. The chapters in the sections on solar magnetism and geomagnetism delve into the problem, presenting a collective exposition of where knowledge presently stands and where it needs to go in the future. It is clear from *Stellar and Planetary Magnetism* that the subject of stellar and planetary magnetism has come a long way, is developing rapidly, and has a long way to go.

E. N. Parker is with the Enrico Fermi Institute, University of Chicago, Chicago, Illinois.

The Scientific Management of Hazardous Wastes

C. B. Cope, W. H. Fuller, and S. L. Willetts, Cambridge Univ. Press, New York, ix + 480 pp., 1983.

Reviewed by Keith S. Porter

According to the jacket of this book, three independent scientists carefully define the limits of scientific knowledge applicable to the management of hazardous wastes. It is claimed that the extrapolation and application of this knowledge is examined, significant areas of uncertainty are identified, and the authors reveal "the fallibility of certain interpretations." It would be more accurate to claim these as possible goals of the book rather than its accomplishments.

Chapter 1, Hazardous Wastes and Their Recycling Potential, includes 11 pages of lists of chemicals, some of which are poorly reproduced. The remaining pages describe, superficially, several recycling schemes. Connections between the chemicals previously listed and the recycling schemes are not given. Concerning the potential for recycling, the last sentence of the chapter reads, "Indeed, the concept of waste recycling, itself a contradiction in terms, is better politics than business." Taken literally, this assertion itself contradicts venerable practice, as the farmer might observe as he transfers waste from his cows to the crops in his field. More pertinently, it can be argued that the recovery of solvents, metals, and oil from waste flows is much more than a political gesture.

The following four chapters, accounting for one third of the book, review legislation of the United Kingdom. A reader may be at times confused about relevance of the material to hazardous wastes. For example, King Edward II's prohibition of the casting of filth from houses in 1309 may have eliminated an unpleasant hazard to pedestrians beneath bedroom windows, but it hardly corresponds to modern notions of hazardous wastes management. It is interesting and useful to establish the context of pollution control within which hazardous wastes are managed, but the links between the context and the management should be explained.

Chapter 5 gives a brief overview of landfills and their leachates because, it is suggested, "the study of domestic refuse landfills and their leachates is an essential first step in understanding the problems which are encountered in the parallel field of hazardous waste management." Although this may be true, the reader is largely left to infer the implications for hazardous waste management.

The next chapter describes landfills and codisposal of hazardous wastes but suggests that this practice cannot be condoned. It is also concluded that codisposal techniques and sanitary landfill practices are diametrically opposed.

Over one quarter of the book is taken up by chapters 8 and 9, which describe, soil processes and toxicology, respectively. These are both primarily elementary summaries of basic scientific understanding. Again, the application of this understanding to the management of hazardous waste is inadequately developed for the reader. In the chapter on soil, the soil is described as something that "encapsulates the earth as material yielding to the foot; follows earth's contours over the land, the surface of hill and valley, mountain peak and gorge, and under water of the lake, seas, and ocean in a thin rind that stands between life and lifelessness. Even to the poet, soil is that "mysterious grit and grime . . . crumbling rock and decaying life, once life. . . abrading by wind and water. . .weathering into soil—Mother Earth." To the farmer it equates to fruit and grains and cattle. To the chemist soil characteristically is "rock on its way to the ocean." The geochemist may think of soil as the soft insoluble earth rind that turns soluble only to precipitate insoluble again as it follows in some reasonable manner the pathway of thermodynamics" (p. 263).

Efforts of technical authors to enliven their text with literary graces are to be particularly applauded. However, this and other passages in the book are careless and cause more discomfort than pleasure. Literary gems can be born out of unlikely "soil," but they will not shine without much polishing.

The last three chapters outline options for treatment, disposal, risk assessment, and cost benefit analysis. For this reviewer, the two

Books *(cont. on p. 414)*

Books (cont. from p. 413)

best and most interesting chapters in the book are those that discuss various methods of disposal ranging from solidification to incineration. These two chapters best meet the title of the book in describing directly the actual management of hazardous wastes at least *in the sense of disposal. In the sense of production*, transport, and storage of hazardous wastes there is very little in the book. Likewise, the management of spills and accidental discharges or emissions is also not directly discussed.

Overall, the book is marred by insufficient cohesion and structure. Key questions in the management of hazardous wastes are what hazardous wastes are produced, how are they produced, and in what quantities? How, when, and where are they disposed of, and what are the consequences and options? It might be objected that much of this knowledge is unavailable. The question in response would then be, What don't we know, how significant is our ignorance and what should be done? One of the most important uncertainties, facing the United States at least, concerns the so-called "orphan" hazardous waste dumps for which there is little if any information. The scientific understanding that can be applied to the detection, characterization, and treatment of such hazardous waste sites so management priorities and responses can be made is not discussed in the book.

Finally, the book is marred by sloppy editing, uncharacteristic of the Cambridge University Press. For example, on page 249 we have "...the ionic strength of the leachate falls from start to pass through a minimum around 200 days and then increases so that at around 350 days it is almost equal to that in the first 50 days of operation. ...Nickel falls from 1 mg l^{-1} at 50 days through a minimum at 200–250 days and then rises again to 1 mg l^{-1} at 350 days." The first of these sentences is gibberish. The second suggests some unconventional physics to account for "nickel falling through its minimum." Another problem for the reader is that results are sometimes only vaguely or ambiguously cited. In querying one set of results, this reviewer decided to check the source, which was a paper coauthored by one of the authors of the book. The paper was found not contain the results credited to it. Such irritations are not helped by minor technical lapses such as acute toxicity being referred to as "a single exposure of duration measured in seconds, minutes, or hours." In fact, acute exposure can be multiple.

In summary, this book has shortcomings many if not most of which can be attributed to very poor editorial work. Despite the shortcomings, the authors convey a sense of having considerable collective experience applicable to hazardous waste management. The book contains a lot of information and at least would make background reading for those concerned with hazardous waste management.

Keith S. Porter is with the Center for Environmental Research, Cornell University, Ithaca, NY 14853.

Classified

RATES PER LINE

Positions Available, Services, Supplies, Courses, and Announcements: first insertion $5.00, additional insertions $4.25.

Positions Wanted: first insertion $2.00, additional insertions $1.50

Student Opportunities: first insertion free, additional insertions $2.00.

There are no discounts or commissions on classified ads. Any type style that is not publisher's choice is charged at general advertising rates. *Eos* is published weekly on Tuesday. Ads must be received in writing by Monday, 1 week prior to the date of publication.

Replies to ads with box numbers should be addressed to Box ___, American Geophysical Union, 2000 Florida Avenue, N.W., Washington, DC 20009.

For more information, call **202-462-6903** or toll free **800-424-2488**.

POSITIONS AVAILABLE

Assistant Professor/Atmospheric Sciences. A tenure track Assistant Professor position will be available in the fall of 1985 at the University of Kansas. Applicants for this position must have a Ph.D. in meteorology or atmospheric science, capability and interest in teaching synoptic meteorology at the advanced undergraduate level, and a strong interest and potential for developing an active research program. Preferred qualifications include postdoctoral research experience and a strong publication record. Duties of this position will include teaching undergraduate meteorology in a B.S. degree program, conducting a vigorous research program, and participating in the resposibilities of the Department of Physics and Astronomy. Salary will depend upon qualifications. Qualified applicants are invited to submit résumes or curricula vitae, bibliographies, narrative statements of research and teaching interests, and the names, addresses and telephone numbers of three references to Professor J. P. Davidson, Chairman, Department of Physics and Astronomy, University of Kansas, Lawrence, Kansas 66045. The closing date is November 15, 1984.

An affirmative action/equal opportunity employer. Applications are sought from all qualified people regardless of race, religion, color, sex, disability, veteran status, national origin, age or ancestry.

The University of Calgary/Assistant Professor Geophysics. The University of Calgary, Department of Geology and Geophysics, invites applications for the position of Assistant Professor of Geophysics. The Appointee will be expected to conduct research and supervise students in the field of exploration geophysics or related areas (seismic or non-seismic) and to teach courses at both the graduate and undergraduate levels. A Ph.D. is required.

The appointment will be made at or close to the base level of the Assistant Professor salary range *which is currently $29,741 (subject to change as of* July 1, 1984).

The Geophysics Group within the Department of Geology and Geophysics emphasizes research in the area of exploration methods. Equipment is available and operational for field operations in reflection seismic (DFS III and IV), EM(Elfast, MaxMin, Gem 8), IP(Huntec MK 4, Phoenix IPT-1 2–5KW), Magnetics(CTF SQUID) and gravity(Worder) A Perkin Elmer 3240 computer i available in the Department which has also been selected as the location for the LITHOPROBE processing centre. Present areas of research include experimental and theoretical aspects of seismology, seismic stratigraphy, experimental and theoretical studies of electrical methods, crustal studies and seismic signal analysis.

All applicants are encouraged to apply but preference will be given to Canadian citizens and permanent residents.

Applicants should forward a detailed curriculum vitae and three letters of reference prior to August 15, 1984 to:

Dr. A.E. Oldershaw, Head
Geology and Geophysics
The University of Calgary
Calgary, Alberta T2N 1N4
Canada

Hydrogeologist. Applications are invited for a non-tenure track academic research appointment in hydrogeology to be filled at the instructor or assistant professor level. This position will have broad research responsibilities in one or more of the following areas: regional and site-specific hydrogeological studies, hydrogeologic and hydrochemical aspects of surface coal mining and reclamation, and assessment of aquifer characteristics by aquifer testing and hydrochemical evaluations. The position entails considerable field work and will be located in Billings, Montana. Candidates must have a M.S. degree in hydrology or geology (Ph.D. preferred) and at least three years of hydrogeological experience, with emphasis on aquifer testing and related work. Knowledge of drilling and the geology of northeastern Montana preferred. The closing date for applications is June 22, 1984. Salary will be $24,000—$29,000/year depending upon education and experience. Applications with resume and names and telephone numbers of three references should be sent to: Director, Montana Bureau of Mines and Geology, Montana College of Mineral Science and Technology, Butte, MT 59701.

An EEO/AA Employer.

Faculty Research Assistant. Position is in the Department of Meteorology, University of Maryland, College Park. Opportunity to work with faculty in a number of research studies involving climate modelling, satellite profilers, and mesoscale analysis. Special emphasis on graphical output from computer models, and diagnostic routines using meteorological data, including satellite and radar imagery. Graphics development will be done on a local microcomputer network and remote host computer. Applicant must be working currently in areas of computer science, applications programming and meteorology. BS in Computer Science or Meteorology required; MS desirable. Experience in FORTRAN essential; experience in UNIX, Pascal and C-language desirable. Appointment is for one year with renewal opportunity. Salary negotiable within range of $18,000 to $30,000. Contact Dr. David Rodenhuis, Department of Meteorology, University of Maryland, College Park, MD 20742; telephone 301-454-2708. Applications received before July 15, 1984 will receive full consideration.

The University of Maryland subscribes to a policy of equal educational and employment opportunity. The University of Maryland under Title IX of the education amendment of 1972, does not discriminate on the basis of sex in admission, treatment of students or employment.

Postdoctoral Research Associate Positions/Geophysics and Igneous Geochemistry. The University of Maine at Orono (UMO) has postdoctoral openings for a solid earth geophysicist and an igneous geochemist. We seek a geophysicist who wishes to advance fundamental understanding of past and current thermal histories of the Appalachian Orogen in New England and elsewhere. The geochemist would be expected to investigate volcanic and plutonic suites in the Appalachians in Maine and in other terranes. Current funding permits appointments for at least 12 months. Subject to arrival of anticipated funding, the appointments could be extended to two years. Both appointments could start as early as August 1, 1984. Excellent facilities for geothermal research, computer applications, petrologic research and geochronologic studies exist at UMO. Additionally, limited funds are available for travel and research, and the appointees will be encouraged to generate exterior support individually or through cooperation with existing faculty. Please send inquiries, a vita, a list of referees, and a description of research interests to Edward R. Decker or Daniel R. Lux, Department of Geological Sciences, 110 Boardman Hall, University of Maine at Orono, Orono, Maine 04469. Telephone calls may be made to 207-581-2152, and forwarded to Decker or Lux.

The University of Maine is an equal opportunity/affirmative action employer.

Senior or Senior Project Hydrogeologist/Hydrologist. A newly-formed hydrogeology and engineering consulting firm, The Mark Group, seeks a mature, experienced hydrogeologist or hydrologist for an immediate filling of a senior technical position in the Las Vegas office. Ongoing and projected investigations will emphasize water resources development, hazardous waste, and geotechnical engineering projects. Principal project work is in California, Nevada, and Arizona. Prefer applicants with minimum four years similar experience and M.S. degree from a recognized program. Strong written and verbal communication skills and overall initiative are required. Professional registration desirable. Please send resume, references. Salary and bonus commensurate with training, experience, and productivity. Ownership participation anticipated. Send letter of interest, resume, sample key reports or reprints to:

Dr. Robert F. Kaufmann, Principal
The Mark Group
7265 West Coley Avenue
Las Vegas, Nevada 89117
702-873-7428

Physical Oceanographers. The Marine Life Research Group of the Scripps Institution of Oceanography invites physical oceanographers to apply for a research position. The research equivalent of the professional series (Ph.D or equivalent required), to study the circulation of the California current and eastern north pacific, support is offered for two years. After which the candidate may be expected to generate all or part of continuing support.

Salary range $25,100—46,900. Level of appointment to be based on qualifications. Position start date from 1 September 1984.

Please send resume and at least three references to Director, Marine Life Research Group, A-030, Scripps Institution of Oceanography, La Jolla, California 92093 by August 1, 1984.

The University of California, San Diego is an equal opportunity/affirmative action employer.

Plan to Attend

The Second International School for Space Simulations

February 4–15, 1985
Kapaa, Kauai, Hawaii

Lectures will be presented on basic simulation techniques as well as on recent results on observations and theory.

Travel fellowships will be available for graduate students, postdoctoral fellows, and beginning investigators.

Organizing Committee:
M. Ashour-Abdalla (UCLA, USA)
P. J. Coleman, Jr. (UCLA, USA)
R. Gendrin (CNET/CNRS, France)
H. Matsumoto (Kyoto Univ., Japan)
T. Obayashi (ISAS, Japan)
H. Okuda (Princeton Univ., USA)
T. Sato (Hiroshima Univ., Japan)

Program Committee:
P. Banks (USA)
T. Birmingham (USA)
J. M. Dawson (USA)
C. T. Dum (FRG)
M. Hudson (USA)
B. Hultqvist (Sweden)
I. Kimura (Japan)
J. Kindel (USA)
A. Nishida (Japan)
H. Oya (Japan)
P. Palmadesso (USA)
D. Papadopoulos (USA)
D. Peacock (USA)
R. Sagalyn (USA)
M. Schulz (USA)
S. Shawhan (USA)
T. Tamao (Japan)

Program, registration and housing information will be available by July 30. To be placed on the School mailing list write to:

D. A. Dutton
ISSS2, IGPP
UCLA
Los Angeles, California 90024.

The University of Manitoba
Civil Engineering

WATER RESOURCES—SYSTEMS ANALYSIS

The Department of Civil Engineering is currently building an effort in civil engineering systems analysis, and has an opening in water resources—systems analysis. The successful candidate will be expected to teach undergraduate and graduate courses in water resources with a systems emphasis, as well as to establish a research effort in this area.

A Ph.D. in civil engineering is required. The University encourages both women and men to apply. In accordance with Canadian immigration requirements, this advertisement is directed to Canadian citizens and permanent residents.

The position is at the assistant professor level with an initial full time appointment for a period of two years beginning September 1, 1985 or later. Please send a curriculum vitae, copies of recent publications, and the names of three referees to: ***Prof. H. Cohen, Head, Department of Civil Engineering, The University of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2.***

Research Assistant Professor/Shallow Water Simulation. A two-year, non-tenure track appointment is available at Dartmouth College. Primary emphasis is on research in hydrodynamic and water quality simulation for estuaries, lakes, and coastal waters. The position also involves teaching one course per year. Additional opportunities exist for involvement in Geophysics, Numerical Methods, or Cold Regions programs.

Applicants must hold the Ph.D. in any relevant scientific discipline. Ability with finite elements and/or boundary elements is strongly favored.

Desired start date is October 1, 1984. Renewal of initial appointment is possible, contingent upon generation of additional research funding. Send resume with three referees and dissertation abstract by August 15 to:

Professor Daniel R. Lynch
Thayer School of Engineering
Dartmouth College
Hanover, New Hampshire 03755
Dartmouth College is and EEO/AA employer.

Texas A&M University/Seismic Stratigraphy.
The Department of Oceanography in the College of Geosciences at Texas A&M University has an opening for a Ph.D. with specialization in the field of seismic stratigraphy. This tenure track position is at the assistant professor level. Salary is negotiable depending upon experience and qualifications. This position will be available pending final approval.

The successful applicant will be expected to teach undergraduate courses in general oceanography, a graduate course in seismic stratigraphy, and may develop graduate courses of his/her own design. He or she will also be epxected to conduct a vigorous research program.

Applicants should submit a vita along with a letter describing his/her research and teaching goals and the names of five persons for reference to Professor Robert O. Reid, Head, Department of Oceanography, Texas A&M University, College Station, Texas 77843. The closing date for applications is 15 July 1984.

Texas A&M University is an affirmative action/equal opportunity employer.

Research Associate/Research Technician. The University of Maine at Orono (UMO) has an opening for a research associate/research technician who would work in a small geophysical group. We seek an individual who can use and maintain modern digital electronic equipment; for example, multichannel analysers, I/O interfaces for microcomputers, digital plotters and digitizing tablets. Familiarity with BASIC and FORTRAN will be needed, and some geophysical field work may be required as part of the duties of the appointee. Current funding permits an appointment for at least 12 months. Subject to arrival of anticipated funding, the appontment period could be extended to two years, or longer. Call Edward R. Decker at 207-581-2158 or 207-581-2152 about the position. Otherwise, send inquiries, a vita and a list of at least three references to Edward R. Decker, Department of Geological Sciences, 110 Boardman Hall, University of Maine at Orono, Orono, ME 04469.

The University of Maine is an equal opportunity/affirmative action employer.

Research Geophysicist/U.S. Geological Survey. The Office of Earthquake, Volcanoe, and Engineering, Branch of Tectonophysics is soliciting interest from persons with either a record of demonstrated ability or outstanding potential for research in one or more areas of Branch activity. The Branch of Tectonophysics carries out a vigorous program in the areas of crustal deformation, in-situ stress and physical properties in regions of particular interest to earthquake and volcanoe hazards. Additional Branch activities include laboratory measurements of rock and mineral deformation in conditions appropriate to the crust and mantle. The Branch is particularly interested in a geophysicist with expertise in the aquisition, analysis, and interpretation of crustal deformation data.

All interested persons should submit a detailed resume of education, experience, summary of interests and research intentions and an appropriate salary level commensurate with experience by 20 July 1984 to:

Wayne Thatcher
Branch of Tectonophysics
U.S. Geological Survey
345 Middlefield Road, MS 977
Menlo Park, CA 94025

Should a position become available in the Branch, you will be notified of the competitive Federal employment application requirement.

GEOPOTENTIAL RESEARCH MISSION SCIENTIFIC CONFERENCE

A Geopotential Research Mission Scientific Conference will be held on October 29–31, 1984 at the University of Maryland. The purpose of the conference is to discuss interpretation and application of variations of the earth's gravity and magnetic fields such as the Geopotential Research Mission is planned to measure. The subject areas of the conference are:

Dynamics and structure of the sub–oceanic lithosphere
Dynamics and structure of the continents
Mantle convection
Dynamics of the core
Ocean circulation

In view of the diverse nature of the topics, it is planned not to include measurement or data analysis techniques. There will be a number of invited papers but there will be time for shorter contributed papers or poster papers.

The conference will be co–chaired by W.M. Kaula and C.G.A. Harrison.

Those interested in presenting a paper at the conference are urged to submit an extended (2–3 page) abstract of their contribution by August 29, 1984. These, and enquiries concerning attendance at the conference should be addressed to:

Louis S. Walter
Code EE–8
NASA Headquarters
Washington, D.C. 20546
Telephone: 202–453–1675

Meetings

Announcements

AWRA Conference

Aug. 12–17, 1984 20th Annual AWRA Conference and Symposium, Washington, D. C. (Kenneth D. Reid, Executive Director, American Water Resources Association, 5410 Grosvenor Lane, Suite 220, Bethesda, MD 20814; tel.: 301-493-8600.)

The conference theme is "Overcoming Institutional and Technical Constraints to Water Resources Management." The program features 17 technical sessions on such topics as institutions for managing regional water resources systems; data needs for analyzing the performance of water resources systems; models for coordination of water resources plans and programs; research to support improved water management; regional water resources planning and management; state-federal relationships; assignment of responsibilities; and assessing the nation's water resources.

The topic of the symposium is "Options for Reaching Water Quality Goals." The session will be keynoted by Rep. James H. Scheuer (D-N.Y.), chairman of the Subcommittee on Natural Resources, Agricultural Research, and Environment of the House Science and Technology Committee.

Chemical Oceanography

Aug. 13–17, 1984 Gordon Research Conference on Chemical Oceanography, Meriden, N. H. Chairman: William Sackett. (Alexander M. Cruickshank, Director, Gordon Research Conferences, University of Rhode Island, Kingston, RI 02881–0801; tel.: 401-783-4011.)

Among the topics to be discussed at this Gordon Research Conference on chemical oceanography are isotopic signals; carbon 14 and other tracers in the oceans; sulfur compounds and their cycles; marine chemistry; and biogeochemical processes.

William Sackett is the conference chairman. Robert Berner is the vice chairman. Discussion leaders include K. Turekian, P. Quay, M. Andrea, E. Goldberg, and P. M. Williams.

Groundwater Models

Aug. 15–17, 1984 Conference on Practical Applications of Groundwater Models, Columbus, Ohio. Sponsors: National Water Well Association, International Groundwater Modeling Center. (David Nielsen, Conference Coordinator, National Water Well Association, 500 West Wilson Bridge Rd., Worthington, OH 43085; tel.: 614-846-9355.)

The conference will feature contributed and invited papers on state of the art groundwater models and their practical applications. The conference will be structured to be informative to seasoned practitioners as well as novices in the field.

Organic Geochemistry

Aug. 20–24, 1984 Gordon Research Conference on Organic Geochemistry, Plymouth, N. H. Chairman: Keith Kvenvolden. (Alexander M. Cruickshank, Director, Gordon Research Conferences, Univ. of Rhode Island, Kingston, RI 02881–0801; tel.: 401-783-4011.)

Among the topics to be discussed at this Gordon Research Conference on organic geochemistry are the carbon cycle; geochemical biomarkers; humic substances; oil and gas deposit occurrences.

Keith A. Kvenvolden is the chairman of the conference. Robert H. Reitsema is vice chairman. Discussion leaders are D.J. Des Marais, W.K. Seifert, G.E. Claypool, and P.G. Hatcher.

Ophiolites Through Time

Nov. 13–15, 1984 Ophiolites Through Time, Nancy, France. (Jacqueline Desmons, Université de Nancy 1, Faculté des Sciences, Laboratoire de Pétrologie, B.P. no. 239, F-54506 Vandoeuvre-lès-Nancy Cedex, France.)

The deadline for abstracts is September 1, 1984.

The conference will cover the evolution of ophiolites through time and its appraisal. The origin, chemical composition, petrographic sequence, inferred mode of emplacement, and the structural environment of ophiolitic basic-ultrabasic associations from Proterozoic to Late Cenozoic ages will be compared. Reports on the radiometric dating of ophiolites, methods, and results will also be included. Data permitting basic-ultrabasic associations in Proterozoic or Paleozoic paleosutures to be interpreted as ophiolites will also be welcome. As in former ophiolite conferences, an open session will be dedicated to contributions on general ophiolitic topics.

Quaternary of Virginia

Sept. 26–29, 1984 Symposium on the Quaternary of Virginia, Charlottesville, Va. Sponsor: Virginia Division of Mineral Resources. (S. O. Bird, Virginia Division of Mineral Resources, Box 3667, Charlottesville, VA 22903; tel.: 804-293-5121.)

August 31 is the deadline for submission of contributed posters.

Among the topics to be covered are late quaternary climates of the middle Atlantic region; Quaternary geomorphology in Virginia; Quaternary fossils; mammalian extinctions; late prehistoric and protohistoric large mammal zoogeography of Virginia; and the study of Quaternary vertebrates in Virginia.

A field trip is planned for September 29 to mammal and Indian sites at Saltville, Va.

The Geophysical Year calendar last appeared in the June 5, 1984, issue of *Eos*.

Meetings (cont. on p. 416)

Meetings (cont. from p. 415)

Meeting Report

The Pre-1958 Atmospheric Concentration of Carbon Dioxide

Introduction

In considering the changes in the atmospheric concentration of carbon dioxide wrought by man's activities, it has been the practice to refer to some presumed value of concentration in the late 19th century as the "pre-industrial" value. Implicit in many of these discussions has been the assumption that prior to the significant use of fossil fuels, the concentration was more or less constant about this value and that fossil fuels were the main reason for the recent departures from it. A value of about 290 parts per million by volume (ppmv) was usually selected as representative of the 19th century concentration. This value arose from a study by *Callendar* [1958], who examined a number of direct chemical measurements made then. If it is assumed that the fraction of fossil fuel produced CO_2 remaining in the air was the same from 1860 to 1958 as it evidently has been since 1958, when systematic measurements began at Mauna Loa Observatory, one calculates a value of about 295 ppmv for the late 19th century.

Recently, a number of studies have suggested a different picture. Not only may lower values of concentration be more appropriate but the assumptions of relative constancy of concentration in the 19th century, and of fossil fuel as the only major source, need to be reexamined. The evidence for these contentions was examined at a meeting in Boulder, Colo., June 22–25, 1983, sponsored by the World Climate Research Program. (The participants are listed in the Acknowledgments and should be considered coauthors of this report.) A full report of the meeting has been issued [*World Climate Research Program*, 1983] and is available from the WMO Secretariat, Case Postale 5, CH-1211, Geneva 20, Switzerland.

The meeting addressed chemical measurements in the 19th and early 20th centuries, some findings from examination of 1900–1950 spectroscopic data, records from ice cores, carbon isotopes in tree rings, and evidence from indirect chemical measurements in the ocean. These will be discussed below as well as some of the implications of the findings. Finally, there were some recommendations for pursuing these techniques.

There are several reasons for wishing to have a record of atmospheric CO_2 concentrations prior to the beginning of the systematic measurements in 1958 using nondispersive infrared techniques (which are not direct chemical measurements). A much longer record would be of considerable assistance in developing and validating carbon cycle models. Such models will be needed to estimate future concentrations of CO_2. Climate models would strongly benefit from a longer record to assist in verification studies. A concentration significantly less than 290 ppmv would imply that fossil fuel use has not been the only significant contributor to the increase. A lower concentration suggests that any contribution to climate change since the 19th century due to CO_2 has been larger than would have been the case had the concentration been higher. On the other hand, a lower concentration would suggest a lower climate sensitivity to CO_2. These implications will be discussed more fully below.

Early Chemical Measurements

There were a number of independent measurements of atmospheric CO_2 made in the 19th century. (It is curious that there seems to have been many more such measurements in the last 30 years of the 19th century than in the first 30 years of the 20th century.) Most of these were made in western Europe. As was mentioned above, *Callendar* [1958] examined many of these and selected a few he believed to have long enough records with good analytical techniques and relatively uninfluenced by local contamination from cities to arrive at his estimate of 290 ppmv as the appropriate "pre-industrial" value, nominally about 1880–1890.

Two sources of possible error in the early measurements must be distinguished: errors inherent in the chemical techniques and sampling errors. In principle, the chemical techniques used were capable of giving values within 1–2% (3–6 ppmv) of the true value, but the precision of the measurements was rarely as high as can now be achieved. The very large number of samples needed to obtain reliable mean values and to assess the precision were almost never made, and there were almost no calibrations against known standards. Short of reconstructing the actual apparatus used, there is almost no way to evaluate the actual measurement accuracy and precision of these early measurements.

We now know a great deal more than did the early investigators about the character of background CO_2 concentrations. Background concentrations show little diurnal variation and a clear annual cycle with a maximum in the late spring and minimum in late summer or early fall. There is a small latitude gradient in the yearly mean value but a more pronounced latitude gradient in the peak-to-trough annual cycle with a peak-to-trough range of about 15 ppmv at the latitude of northwest Europe, diminishing toward the equator. In the southern hemisphere there is only a very small annual cycle. Year-to-year changes are now about 1–2 ppmv, probably within the precision of the older measurement techniques. These characteristics can be expected to be valid in the 19th century and so used to evaluate some of the early records.

Both diurnal and annual cycles in atmospheric stability can produce a CO_2 record biased toward higher values if measurements are made near vegetation. A 24-hour mean value would likely show values too high compared to background, because the daytime photosynthesis drawn down occurs when the air is relatively well mixed whereas the buildup at night due to respiration occurs with a poorly mixed atmosphere.

The same argument can be applied to the annual cycle. The atmosphere in northwest Europe is stable in winter when photosynthesis is at a minimum, whereas it is less stable in summer. Accompanying this are the likely greater emissions from fuel in winter. Thus, it is not surprising that many old records (and some modern ones in Europe) show a winter rather than a spring maximum. This bias, together with the possibility of a regional contamination because of fuel use, suggests the early data from Europe are likely higher than the real background.

Some intriguing data were taken from remote locations in the tropics and the southern hemisphere by *Muntz and Aubin* [1886]. These data—taken all together—suggest a mean value of about 270 ppmv for the southern hemisphere. Because they were taken at remote sites with little annual or diurnal variation by careful scientists, one is tempted to accept them as being background data. But there are problems. The data show a much larger latitude gradient than is found today (the values decreased from the tropics to 50° south by 20–30 ppmv). This suggests problems with sampling or analytical techniques, or possibly problems maintaining sample integrity since CO_2 was trapped in sealed containers and returned to France for subsequent analysis.

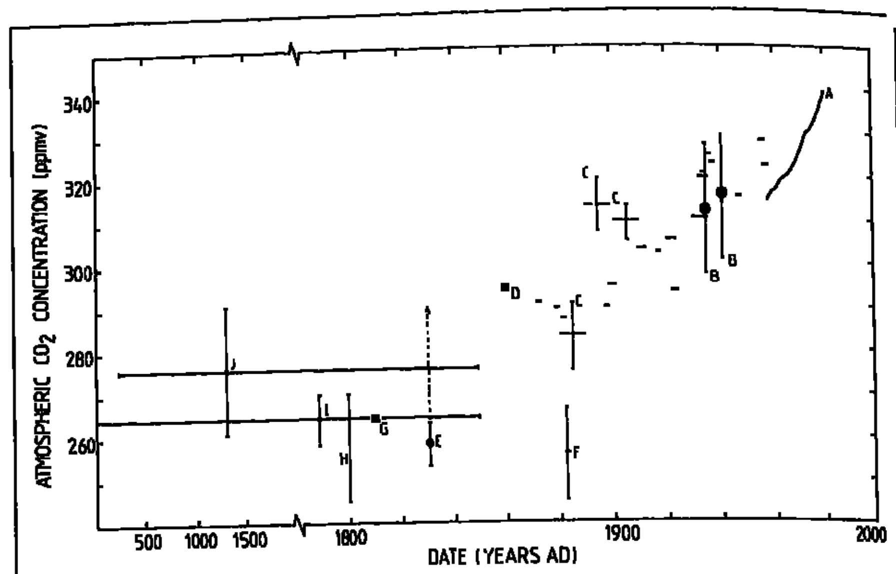


Fig. 1. Estimates of past atmospheric carbon dioxide concentrations. A, measurements from Mauna Loa Observatory [*Keeling et al.*, 1982]. These data are within 1% of the global tropospheric mean. B, based on unpublished analyses of archived solar spectra. C, decadal average data from Montsouris Observatory, Paris, as recently presented by *Stanhill* [1982]. D, model calculation for comparison, extrapolating from "A" assuming fossil fuel combustion to be the only source of CO_2. E, analysis of subsurface ocean waters giving pCO_2 at the time when the waters were in contact with the atmosphere, approximately 150 years ago [*Brewer*, 1978]. The solid bar represents random uncertainties, and the dashed arrow indicates a possible underestimate of up to 25 ppmv. F, air sampled at Cape Horn [*Muntz and Aubin*, 1886]. The standard deviation bar for 39 samples indicates that the variability is uncharacteristically high for southern hemisphere background air. G, typical of model calculations assuming 150 Gt of non-fossil carbon released at about 1900 (see, for example, *Enting and Pearman* [1982], *Enting et al.* [1983], *Pearman et al.* [1983]. H, estimate obtained using models to interpret $^{13}C/^{12}C$ content in tree rings [*Peng et al.*, 1983]. I, CO_2 concentrations in air bubbles trapped in glacial ice, based on results from French and Swiss laboratories [see *Barnola et al.*, 1983], believed to be representative of atmospheric concentrations at the time of trapping. Average for period A.D. 1 to 1850. J, As "H" but with rings from A.D. 235-1850 with data normalized by annual ring growth. Different trees and a different model were used than "H" [*Stuiver et al.*, 1984]. Early observations selected by *Callendar* [1958] as being representative of background air. Note Callendar chose to exclude the Montsouris "C" and Cape Horn data "F" from his analysis.

Analysis of Spectroscopic Data

As sunlight passes through the atmosphere, the molecules in the air absorb radiation at specific wave lengths. The amount of absorption is a function of the molecule properties and abundance. Thus it should be possible to determine the concentration of CO_2 by examining the absorption lines in the solar spectra. The analysis of archived solar spectra offers a way to estimate atmospheric CO_2 concentration prior to the Mauna Loa record. The spectrum of the earth's atmosphere has been recorded with regularity for almost 100 years. The most important of the spectroscopic data were taken as part of the Smithsonian Solar Constant program, which ran from approximately 1902 until 1956. In this program the spectroscopic data were collected for the express purpose of measuring the transparency of the atmosphere. The spectra were collected almost daily at several sites around the world. The bulk of the data that still exists from this program was taken at the Table Mountain Station (altitude 2286 m) in California from 1927 to the late 1950's. The technique for analyzing these spectra is still being developed.

To establish that the spectroscopic data will provide an extension of the current record of atmospheric CO_2 concentrations, the relationship between vertically integrated column densities of CO_2 and surface measurements must be determined. Another issue is whether the old spectroscopic data base can be analyzed with sufficient precision (better than 5% or 15 ppmv) in order to make a useful contribution.

The attempt to establish the relationship between the integrated column and surface measurements is based on 4 years of observations taken at the Kitt Peak National Observatory on an almost monthly basis, weather permitting. A preliminary analysis of these data gave good precision (approximately 1%) and reasonable accuracy, with an average concentration of 340 + 10 ppmv for the period 1978–1981. This is compatible to the average concentration of 337 ppmv observed at Mauna Loa during this same period. The data also appear to contain a signal due to the annual variation of CO_2 concentration. In support of this effort, flask samples of air for separate analysis by National Oceanic and Atmospheric Administration (NOAA) have been collected in conjunction with the spectroscopic program.

A preliminary analysis of the historical Smithsonian data gave encouraging results but was clearly subject to systematic errors. The source of these errors is almost entirely the incomplete knowledge of the spectrobolographic equipment used in the observations. The two dominant sources of systematic error have been identified as scatered light in the instrument and poor knowledge of how the instrument was actually operated.

The most internally consistent analysis thus far gave values of 312 and 316 ppm for 1935 and 1941, respectively. These values are higher than would be expected from the post-1957 record, but the expected values are within the 90% confidence interval of these measurements which is approximately +15 ppmv. (Since the meeting, an improved technique [*Stokes and Barnard*, 1984] has made it possible to separate the errors into random and systematic components. For 1941 the figure is now 311 + 11 ppmv. The 11 ppmv uncertainty is composed approximately of a systematic term of 2 ppmv and a random term of 9 ppmv.) While these remain provisional results, the analysis of this subset of the Smithsonian data suggests that the technique offers considerable promise, and the meeting participants felt it desirable to attempt to analyze all available spectrograms.

Past Atmospheric CO_2 Record From Ice Cores

The process of transforming snow to ice on glaciers and ice sheets traps air within the ice. Below a certain depth the trapped air becomes isolated from the atmosphere and so a sample of "old" air can be obtained whose CO_2 content should under certain conditions reflect the atmospheric composition at the time of ice formation.

Great care is required to extract the air from these bubbles in ice cores and to measure their CO_2 content. In addition, there are several problems in interpreting the resulting data. The CO_2 concentration of the enclosed air may differ from the original atmospheric because of various physical and chemical processes. For example, if the surrounding ice has been subjected to melting and refreezing during its lifetime, spurious results can be obtained because of the high solubility of CO_2 in water. The core drilling process itself may introduce problems particularly if the core has fractured. Some of these problems can be minimized by selecting unfractured cores from very cold sites with no summer melting. When selected in this way, the CO_2 concentration in the bubbles should not differ from that in the atmosphere by more than +15 ppmv.

Another problem arises in assigning a date to the sample. The trapping of the air occurs during the time interval corresponding to the time required for the firn to become ice. This typically takes 100-1000 years, depending on snow accumulation rate and temperature. Neighboring bubbles may have different ages depending on when a particular bubble was occluded. Although the age of the surrounding ice can generally be determined, the bubble's age can differ by 100-1000 years from this age. The time resolution of a sample is determined by the duration of the gas enclosure process, and there remains some controversy about the assignment of a specific time interval for this duration.

Despite these uncertainties, which may be reduced in the future, bubbles in old ice are probably the most reliable samples of old atmospheric air. An encouraging result came from an interlaboratory comparison between the groups at Bern and Grenoble [*Barnola et al.*, 1983]. The results from the same ice cores were within the experimental error limit of 3%. Results obtained in the two laboratories gave mean atmospheric concentrations between 258 and 270 ppmv for the time interval between 500 B.C. and A.D. 1850. Very recent measurements with a new extraction technique at Bern, however, suggest these values may be too low by about 10–20 ppmv. Further investigation is needed. In addition, preliminary results suggest that natural fluctuations on the order of 10 ppmv could have occurred during the A.D. 1500–1850 period [*Raynaud and Barnola*, 1984].

CO_2 Values Derived From ^{13}C and ^{14}C Records in Trees

The history of the $^{14}C/^{12}C$ and $^{13}C/^{12}C$ isotope ratios of atmospheric CO_2 provides additional information on past changes in atmospheric CO_2 content. Different information is derived from the two isotopes. Whereas the stable ^{13}C and ^{12}C are of primordial origin, the natural ^{14}C currently encountered in our carbon reservoirs is produced by cosmic radiation in the upper atmosphere. The half-line of ^{14}C is short enough (5600 years) so that no ^{14}C is found in fossil fuels.[ql The $^{14}C/^{12}C$ history of atmospheric carbon reflects changes in the size of, and exchange rate among, the various terresterial carbon reservoirs and the variable ^{14}C production rate in the atmosphere.

With the current available knowledge of solar modulation and earth geomagnetic change it is possible to calculate, with the aid of a carbon reservoir model, the natural atmospheric ^{14}C levels of the 19th and 20th centuries. The deviation between these calculated ^{14}C concentrations and ^{14}C measurements in tree rings is attributed to the lowering of ^{14}C concentrations by ^{14}C-free fossil fuel CO_2 release. This ^{14}C lowering can be followed up to 1952 when nuclear bomb testing added large quantities of ^{14}C to the atmosphere.

The calculated amount of ^{14}C-free fossil fuel CO_2 needed to explain the ^{14}C record agrees with the CO_2 emissions derived from fuel production data within 10%. This agreement points toward the reliability of the carbon reservoir model used.

In assimilating carbon from the atmosphere, photosynthesis discriminates against the heavier carbon isotope ^{13}C. The $^{13}C/^{12}C$ ratio in organic matter is about 1.8% lower than that in the atmosphere. Fossil fuels, being formed from organic matter, have a similar ^{13}C deficiency. Thus changes in the size of the biosphere should introduce changes in atmospheric $^{13}C/^{12}C$ ratios, and so a history of these changes should give a record of CO_2 added to or subtracted from the atmosphere because of changes in the size of the biosphere as well as by fossil fuel combustion.

The $^{13}C/^{12}C$ records of tree rings are used to derive the atmospheric $^{13}C/^{12}C$ signal. The tree isotope ratio not only reflects the atmospheric ratio but also a variable fractionation against the heavier ^{13}C isotope during photosynthesis. For an accurate interpretation of the $^{13}C/^{12}C$ record of trees, the mechanism(s) that induce variable fractionation have to be understood. The rate of assimilation, leaf conductance and atmospheric CO_2 pressure affect the $^{13}C/^{12}C$ ratios in plants as well as the number of leaves. Thus, it is not surprising that a multitude of $^{13}C/^{12}C$ trends has been found in trees from the past centuries.

$^{13}C/^{12}C$ records from trees from Pacific coastal sites (53°S to 58°N latitude) [*Stuiver et al.*, 1983], yield model calculated pre-industrial atmospheric CO_2 levels averaging 276 ppmv for the A.D. 234-1850 interval. Appreciable interdecadal variability exists, however, running from as low as 230 ppmv to as high as 310 ppmv. A substantial portion of this variability probably results from tree-induced variations in the $^{13}C/^{12}C$ record despite attempts to eliminate some of them. $^{13}C/^{12}C$ records from mainly European and eastern U.S. sites show a larger biospheric signal, and the model calculations of this signal yield an atmospheric CO_2 level of 242 ppmv around A.D. 1800 [*Peng et al.*, 1983]. (A recent reevaluation by the same authors [*Peng et al.*, 1984] yielded a value of about 266 ppmv.) The same $^{13}C/^{12}C$ record, when used in the Stuiver et al. model, yielded a pre-industrial value of 230 ppmv around A.D. 1800. Thus, model differences can lead to differences of the order of 10 ppmv in calculated pre-industrial CO_2 content.

Ocean Chemistry Evidence for Pre-Industrial CO_2 Concentrations

There have been recent attempts to detect the ocean CO_2 increase by examining contemporary ocean CO_2 measurements. One scheme used by *Brewer* [1978] is to calculate the partial pressure of CO_2 (pCO_2) of a deep ocean water sample after correction for the rather large changes due to respiration and carbonate dissolution that have occurred during the waters' history. The result is an estimate of the pCO_2 achieved by a particular water sample when it was last at the surface. The requirements for the calculation are: (1) accurate measurements of alkalinity and total CO_2 (the total amounts of CO_2 in all its inorganic chemical forms); (2) the ability to calculate the extent of carbonate dissolution; and (3) accurate knowledge of the respiration coefficient, which is the ratio of the change in total CO_2 to the change in O_2 (This is conventionally calculated from the relative abundance of carbon, nitrogen, phosphorus, and oxygen (the Redfield ratios) and is taken to be 0.768.).

The most accurate and detailed data set available comes from the transient tracers in the Ocean North Atlantic Experiment. Deep waters formed mainly at the surface in high latitudes penetrate into the abyss. The age of these waters can be assigned quite well, both from their radiocarbon content and from the penetration of bomb-produced radionuclides.

The CO_2 system properties have also been measured in these waters. Applying the calculation scheme of *Brewer* [1978], modified to correct for the effects of phosphate and silicate, one can derive an "initial pCO_2" for these waters. A value of 265 ppmv is calculated for water about 150 years old. How accurate is this result, and what does it mean?

The nutrient, salinity, and temperature measurements are highly accurate. The alkalinity data have been subjected to independent checks and appear to be accurate to 0.15%. The total CO_2 data used here have been determined by potentiometric titration and should be treated with caution. Independent checks against the highly accurate gasometric procedure of Keeling show a complex small error in the titration data. The source of this error is not yet clear. Applying the Keeling total CO_2 correction would result in initial pCO_2 values in the deep waters as low as 258 ppmv.

There are other sources of error. Furthermore, the descending surface waters, formed in wintertime, may not be exactly in O_2 saturation equilibrium with the atmosphere, as required by the calculation. The error from this source is, however, likely to be small.

The largest question is how to interpret this number.

North Atlantic waters are cooled faster than they can achieve CO_2 equilibrium with the atmosphere and may sink before achieving equilibrium. Biological activity further lowers pCO_2. Thus marked, CO_2 disequilibria are found in northern surface waters. It is not known what the pCO_2 "label" of the deep waters is at the time of their formation since both surface and intermediate waters, which have equilibriated with the atmosphere at other latitudes, are likely entrained in a complex and unobservable process. The likelihood is that newly formed North Atlantic deep waters descend with a pCO_2 value less than saturation equilibrium.

The estimate of 258 ppmv CO_2 for waters of 150 (+50) years or so age in the deep North Atlantic is thus a lower limit for the atmosphere.

It would, however, be hard to reconcile a value a great deal higher than this with the oceanic data. Values of 290 ppmv, for instance, would present considerable difficulties.

CO_2 Variations During the last 50,000 Years

Ice cores can be used to extend the CO_2 record back over the last 50,000 years. The main features are low CO_2 values (about 200 ppmv) during the last glacial maximum, around 18,000 BP, and a rapid increase to values which generally remained within the interval 260 to 300 ppmv during the Holocene [*Berner et al.*, 1980; *Delmas et al.*, 1980].

One of the most intriguing pieces of information was the recent measurements indicating that during the last glaciation there were several occasions when the atmospheric CO_2 content changed between about 180 and 250 ppmv [*Stauffer et al*, 1984]. The time needed to shift from one value to the other seems to be of the order of only a few centuries. This fact should be considered, not only in attempts to understand the basic regulation mechanism for the atmospheric CO_2 content, but also in the assessments of climate implications of the current period of observed CO_2 increases.

Discussion

Each of the techniques for estimating the older CO_2 values has shortcomings. In some cases the estimates could be improved by further work and likely will be. The group felt that further study of the older chemical records since about 1860 in the light of our knowledge of the characteristics of background data could produce better estimates or at least put more stringent limits on the values. Continued work on the spectroscopic data was encouraged with consideration being given to determining the ratio CO_2/O_2 from the plates to help eliminate some of the errors. Spectroscopic data could be particularly valuable in filling in the period between 1900 and 1958.

The ice core analysis currently seems the best method for determining the pre-1900 values and is the only method available for obtaining values back many thousands of years. The continued study of these cores was encouraged with some thought given to the improvement of the experimental accuracy, to on-site analysis to quantify the gas trapping process and to eliminate contamination during shipment.

The carbon isotope data from tree rings remain tantalizing because they offer the possibility of determining the biospheric contribution to atmospheric CO_2 for many centuries or millenia in the past. Efforts should be made to reconcile the differences among the various attempts to use the $^{13}C/^{12}C$ ratios. Better understanding of physiological effects in isotope fractionation or methods of eliminating their effects in the analyses are needed.

At present the results of CO_2 reconstruction from ocean chemical data are ambiguous, but the technique deserves continued effort. A suggestion to examine isolated seas, such as the Red Sea, might be fruitful as they have a single deep-water formation area and fewer problems with disequilibrium.

Figure 1 represents a summation of the results considered at the meeting. Despite questions and uncertainties associated with each estimate, the group was impressed with the convergence of these techniques on a value (or values) singificantly less than 290 ppmv. It was a general conclusion that the mid 19th century values were not very unlikely to have been less than 250 ppmv or much greater than 290 ppmv. Somewhat subjectively the group felt values between 260 ppmv and 280 ppmv were the most likely prevailing CO_2 concentrations during the mid 19th century.

In addition to lower values in the last century, several other conclusions were drawn from our deliberations. It is probably misleading to refer to a single pre-industrial value in the last century. The group could not plot a curve of most likely rate of change but it seems quite possible CO_2 was increasing with time in the 1800's. Reaching back further in time there was evidence for natural fluctuations at least of order of 10 ppmv in the last few centuries. On the much larger time scale of ice ages, fluctuations of perhaps 100 ppmv are likely. The causes for these fluctuations remain obscure but changes in ocean circulation and biology are logical candidates.

Implications

The meeting participants discussed some of the implications of these findings. First, of course, is the conclusion that 19th century concentrations below 290 ppmv imply that a non-fossil fuel source must have been in effect. A value near 270 ppmv would imply this source was as large as the fossil fuel source between 1860 and 1960. This source is most likely the terrestrial biosphere, a contention supported by the isotope records.

As mentioned above, a back extrapolation of the Mauna Loa record, assuming a constant airborne fraction of the fossil CO_2 input, yields a calculated pre-industrial value of about 294 ppmv. A more sophisticated back extrapolation uses carbon cycle models, calibrated by means of the observed oceanic distribution of either natural or bomb produced ^{14}C. On the basis of the known fossil fuel CO_2 production rates, these models generally predict an atmospheric increase slightly larger than the observed trend from 1958 onward. Therefore, a (small) additional sink, typically of about 10% of the fossil fuel production and in addition to the oceanic CO_2 uptake, has to be asumed for these carbon cycle models to reproduce the observed trend.

With one such model, a lower 19th century value (e.g., 265 ppmv in 1820) implies a non-fossil source large in the 19th century and declining from 1900 to near zero (but positive) about 1970. In this case the model is thus able to reproduce the post-1958 record without recourse to a biospheric sink. This example suggests that lower initial CO_2 values may help solve a problem of current carbon cycle models.

The possible occurrence of significant fluctuations in the past gives additional problems for carbon cycle modeling, however. If forward extrapolation with assumed fossil fuel sources is usedto predict future atmospheric concentrations these other, as yet unidentified, causes of fluctuation will need to be understood.

There are implications for the determination of the response of the climate to increased CO_2. It was noted that if the concentration in 1880 was lower than previously assumed, then there has been a larger effect of CO_2 on the climate of the last 100 years than if the concentration had been greater. A simplified model was shown where the equilibrium response to a doubled CO_2 concentration was taken to be 3.2°C and an effective ocean heat capacity calibrated with bomb-produced ^{14}C data was included. For an initial concentration of 297 ppmv the model [*Siegenthaler and Oeschger*, 1983] gave an 0.26°C warming by 1980 whereas with a 265 ppm initial concentration, the model gave a warming of 0.62°C. Furthermore, the time change of temperatures with the lower initial concentration appeared to fit the northern hemisphere surface temperature data of *Jones et al.* [1982] better than that starting with 297 ppmv. Nevertheless, the temperature record is not fully explained by CO_2 only forcing and indicates that global temperatures have been influenced by additional factors. These factors will have to be better understood before the influence of CO_2 can be extracted from the temperature records.

There is another implication of relatively low 19th century CO_2 concentrations. As pointed out in a recent review of the CO_2 question [*Carbon Dioxide Assessment Committee*, 1983] an ocean response time of 15 years and a warming of 0.5°C up to 1980 can be compatible with an equilibrium temperature change of 4.5°C for doubled CO_2 concentrations if the CO_2 concentration was about 300 ppmv in 1850. If the 1850 concentration was well below 300 ppmv, and other forcing factors did not intervene, the equilibrium temperature change must be below 3°C (as low as 1.50 if the 1850 concentration was 250 ppmv) to avoid inconsistency with the temperature record. It is that temperature record and the Carbon Dioxide Assessment Committee estimate that the 19th century CO_2 concentrations were lower than 290 ppmv led them to conclude that the equilibrium climate response to doubled CO_2 was more likely in the lower half (1.5°–3.0°) of the range suggested by the climate models.

The implications for carbon cycle studies and for validating climate models point up the desirability of establishing the time record of atmospheric CO_2 concentration much better than we have been able to do here.

Acknowledgments

The participants at the meeting were Rumen D. Bojkov, World Climate Research Programme, WMO, Geneva; Peter Brewer, National Science Foundation, Washington, D.C.; William Elliott, NOAA/ERL, Rockville, Md.; Paul Fraser, CSIRO, Division of Atmospheric Research, Aspendale, Victoria; Richard Gammon, NOAA/ERL/GMCC, Boulder, Colo.; Hans Oeschger (chairman), Physics Institute, University of Bern, Bern; Graeme I. Pearman, CSIRO, Division of Atmospheric Sciences, Aspendale, Victoria; James Peterson, NOAA/ERL/GMCC, Boulder, Colo.; Dominique Raynaurd, CNRS/Laboratoire de Glaciologie et Géophysique de l'Environnement, Grenoble; Ulrich Siegenthaler, Physics Institute, University of Bern, Bern; Bernhard Stauffer, Physics Institute, University of Bern, Bern; Gerald M. Stokes, Battelle, Pacific Northwest Labs., Richland, Wash.; Minze Stuiver, Quaternary Isotope Laboratory, University of Washington, Seattle. All participated in the preparation of this report and are coauthors.

References

Barnola, J. M., D. Raynaud, A. Neftel, and H. Oeschger, Comparison of CO_2 measurements by two laboratories on air from bubbles in polar ice, *Nature, 303*, 410–413, 1983.

Berner, W., H. Oeschger, and B. Stauffer, Information of the CO_2 cycle from ice core studies, *Radiocarbon, 22*, 227–235, 1980.

Brewer, P. G., Direct observations of the oceanic CO_2 increase, *Geophys. Res. Lett., 5*, 997–1000, 1978.

Callendar, G. S., On the amount of carbon dioxide in the atmosphere, *Tellus, 10*, 243–248, 1958.

Carbon Dioxide Assessment Committee, *Changing Climate*, National Academy Press, Washington, D. C., 1983.

Delmas, R. J., J. M. Ascencio, and M. Legrand, Polar ice evidence that atmospheric CO_2 20,000 yr B.P. was 50% of present, *Nature, 284*, 155–157, 1980.

Jones, P. D., T. M. L. Wigley, and P. M. Kelly, Variations in surface air temperatures. 1. Northern hemisphere, 1881–1980, *Mon Weather Rev., 110*, 59–69, 1982.

Muntz, A., and E. Aubin, Recherches sur la constitution chimique de l'atmosphère, in *Mission Scientifique du Cap Horn*, Vol. III, pp. A2-A90, Gauthiers, Villars, Paris, 1886.

Peng, T-H., W. S. Broecker, H. D. Freyer, and S. Trumbore, A deconvolution of the tree ring ^{13}C record, *J. Geophys. Res., 88*, 3609–3620, 1983.

Peng, T-H, W. S. Broecker, and H. D. Freyer, Revised estimates 1984.

Siegenthaler, U., Uptake of excess CO_2 by an outcrop-diffusion model of the ocean, *J. Geophys. Res., 88*, 3599–3608, 1983.

Siegenthaler, U., and H. Oeschger, Transient temperature change due to increasing CO_2 using simple models, *Ann. Glaciol.*, in press, 1983.

Stauffer, B., H. Hoffer, H. Oeschger, J. Schwander, and U. Siegenthaler, Atmospheric CO_2 concentration during the last glaciation, *Ann. Glaciol., 5*, in press, 1984.

Stokes, G. M., and J. C. Barnard, Presentation of 20th century atmospheric carbon dioxide record in Smithsonian Spectrographic Plates, *Journal*, in press, 1984.

Stuiver, M., R. L. Burk, and P. D. Quay, $^{13}C/^{12}C$ ratios and the transfer of biospheric carbon to the atmosphere, *J. Geophys. Res.*, in press, 1984.

World Climate Research Program, Report of the WMO (CAS) meeting of experts on the CO_2 concentrations from pre-industrial times to IGY (WCP-53), *Rep. 10*, World Meteorol. Organ., Geneva, 1983.

This information report was written by William P. Elliott, *Air Resources Laboratory, National Oceanic and Atmospheric Administration, Rockville, MD 20852.*

AGU

On July 1, newly elected section and union officers will assume their roles as members of the Council. Each new section president-elect will serve 2 years in that capacity, then 2 years as section president.

These are the Council members who will serve through June 30, 1986.

Charles L. Drake
President, AGU
Professor of Geology, Dartmouth College

James A. Van Allen
Past President, AGU
Carver Professor of Physics and Head of Department, University of Iowa

Peter S. Eagleson
President-Elect, AGU
Edmund K. Turner Professor of Civil Engineering, Massachusetts Institute of Technology

Peter M. Bell
General Secretary, AGU
Geophysicist, Geophysical Laboratory

Juan G. Roederer
Foreign Secretary, AGU
Director, Geophysical Institute, University of Alaska

A. F. Spilhaus, Jr.
Executive Director, AGU

The section officers for the biennium are

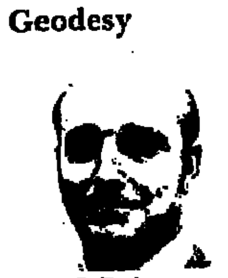
Atmospheric Sciences

Fred D. White
President, Atmospheric Sciences Section; Staff Officer, Board on Atmospheric Sciences and Climate, National Research Council

Ralph J. Cicerone
President-Elect, Atmospheric Sciences Section; Director, Atmospheric Chemistry and Aeronomy Division, NCAR

Rex J. Fleming
Secretary, Atmospheric Sciences Section; Director, Office of Climate and Atmospheric Research, NOAA, Rockville

Geodesy



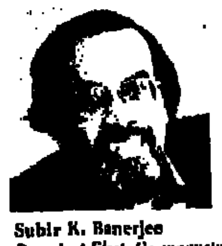
Byron D. Tapley
President, Geodesy Section; Director, Center for Space Research and W. R. Woolrich Professor, University of Texas, Austin

John D. Bossler
President-Elect, Geodesy Section; Director, Charting and Geodetic Services NOS/NOAA, Rockville

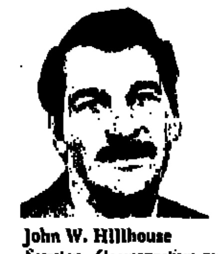
James G. Marsh
Secretary, Geodesy Section; Geophysicist, Geodynamics Branch, Goddard Space Flight Center

Geomagnetism and Paleomagnetism

Neil D. Opdyke
President, Geomagnetism and Paleomagnetism Section; Chairman, Department of Geology, University of Florida

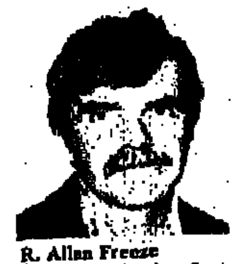


Subir K. Banerjee
President-Elect, Geomagnetism and Paleomagnetism Section; Professor, Department of Geology and Geophysics, University of Minnesota

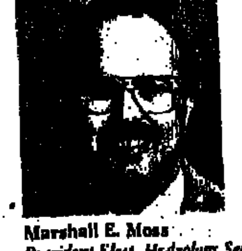


John W. Hillhouse
Secretary, Geomagnetism and Paleomagnetism Section; Geophysicist, U.S. Geological Survey, Menlo Park

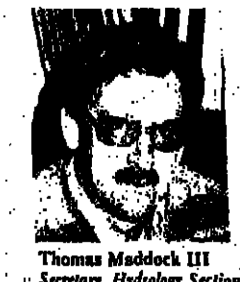
Hydrology



R. Allan Freeze
President, Hydrology Section; Professor, Department of Geological Sciences, University of British Columbia



Marshall E. Moss
President-Elect, Hydrology Section; Chief, Surface Water Branch, U.S. Geological Survey, Reston

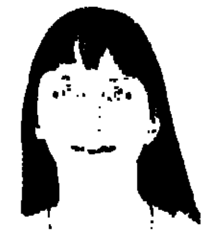


Thomas Maddock III
Secretary, Hydrology Section; Professor, Department of Hydrology and Water Resources, University of Arizona

Ocean Sciences

Joseph L. Reid
President, Ocean Sciences Section; Professor of Physical Oceanography, Scripps Institute of Oceanography

Arnold L. Gordon
President-Elect, Ocean Sciences Section; Professor, Lamont-Doherty Geological Observatory



Barbara M. Hickey
Secretary, Ocean Sciences Section; Research Associate Professor, School of Oceanography, University of Washington

Planetology

Laurence A. Soderblom
President, Planetology Section; Geophysicist, U.S. Geological Survey, Flagstaff

Sean C. Solomon
President-Elect, Planetology Section; Professor of Geophysics, Massachusetts Institute of Technology

Raymond E. Arvidson
Secretary, Planetology Section; Professor, Department of Earth and Planetary Sciences, Washington University

Seismology

Lynn R. Sykes
President, Seismology Section; Higgins Professor of Geological Sciences, Lamont-Doherty Geological Observatory

Stewart W. Smith
President-Elect, Seismology Section; Professor, Geophysics Program, University of Washington

William L. Ellsworth
Secretary, Seismology Section; Chief, Seismology Branch, U.S. Geological Survey, Menlo Park

Solar-Planetary Relationships

George C. Reid
President, Solar-Planetary Relationships Section; Deputy Director, Aeronomy Laboratory, NOAA, Boulder

R. A. Helliwell
President-Elect, Solar-Planetary Relationships Section; Professor of Electrical Engineering, Stanford University

G. G. Sivjee
Secretary, Solar-Planetary Relationships Section (Aeronomy); Professor of Physics and Chairman, Department of Physics, University of Alaska

Leonard F. Burlaga
Secretary, Solar-Planetary Relationships Section (Cosmic Rays); Astrophysicist, Interplanetary Physics Branch, Goddard Space Flight Center

George K. Parks
Secretary, Solar-Planetary Relationships Section (Magnetospheric Physics); Professor, Geophysics Program, University of Washington

Bruce T. Tsurutani
Secretary, Solar-Planetary Relationships Section (Solar and Interplanetary Physics); Member of Technical Staff, Space Physics Section, Jet Propulsion Laboratory

Tectonophysics

Thomas J. Ahrens
President, Tectonophysics Section; Professor of Geophysics, California Institute of Technology

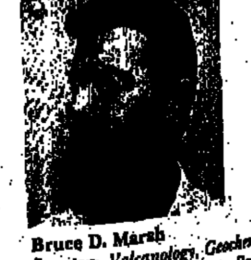
Richard P. Von Herzen
President-Elect, Tectonophysics Section; Chairman, Department of Geology and Geophysics, Woods Hole Oceanographic Institution

Barry Parsons
Secretary, Tectonophysics Section; Department of Earth and Planetary Sciences, Massachusetts Institute of Technology

Volcanology, Geochemistry, and Petrology

G. Brent Dalrymple
President, Volcanology, Geochemistry, and Petrology Section; Research Geologist, U.S. Geological Survey, Menlo Park

Robin Brett
President-Elect, Volcanology, Geochemistry, and Petrology Section; Geologist, U.S. Geological Survey, Reston



Bruce D. Marsh
Secretary, Volcanology, Geochemistry, and Petrology Section; Professor, Department of Earth and Planetary Sciences, The Johns Hopkins University

AGU Membership Applications

Applications for membership have been received from the following individuals. The letter after the name denotes the proposed primary section affiliation.

Regular Members

Leon H. Allen (H), Douglas Anunon (H), David W. Belanger (H), James Bollwerk (S), James Campbell (G), Wayne H. Cannon (G), Catherine Chauvel (V), Nancy L. Cichowicz (H), Daniel E. Clements (V), Stephen K. Dobos (V).

Richard A. Eichinger (G), Woodland E. Erlebach (H), Adil B. Hassam (SS), William F. Haxby (T), J. Michael Heinick (G), Donald M. Henderson (V), Bruce C. Hermiter (SA), Dale Hernquist (G), Joseph Paul Hodych (GP), Susan E. Humphris (V).

Richard A. Kerr (O), R. W. D. Killey (H), H. Vernon Knapp (H), Kun-Hock Koo (T), Peter M. Kroger (G), Lung-Fa Ku (O), James Lange (SS), David R. LaRochelle (G), Samuel N. Luoma (O), Hugh B. Lynch (H).

Masaru Maeda (O), Robert A. Matzener (H), James R. McCullough (O), Cindy A. McMullen (T), Peter J. Melvin (G), Richard C. Miller (V), Horst Mueller (G), Susan Nava (S), Keran O'Brien (SC), W. Brechner Owens (O).

Ho Jung Paik (G), Don F. Parker (V), Jean E. Paterson (T), Dave Pendleton (G), Clara Podpora (V), Vickie L. Poole (H), Jeffrey R. Resnick (S), Joseph Romig (P), Dinesh Chandra Singhal (H), Catherine Skokan (GP), Ken Smith (SA), Melissa Strait (V), Michael P. Sulzer (SA).

Frank Triska (H), Jean Vernin (A), Grazia Verrone (G), Mark A. Vincent (G), Alexander Wagini (GP), Frederick Wieland (G), Chris Wood (S), I-Pai Wu (H), Eric A. Yasukawa (SS).

Student Status

Lawrence Anovitz (V), Athanasios Arvanitis (S), Sinnadurai Babusukumar (O), Jon Eric Barton (V), Rodney Baumann (V), Jeremy Bloxham (GP), Stephen Braun (GP), Mark Brearley (V).

Nancy M. Caffall (GP), R. Chaudet (V), Gianming Chen (S), Lisa Cirbus (A), Ronald Collette (H), Terrence Connelly (V), James A. D. Connolly (V), David L. Couch (S), John Cox (S).

Brian N. Damiata (T), Howard G. Demars (SA), Karl-Heinz Eigner (T), Maureen M. Enochs (S), Wu Fang (GP), Phillip B. Gans (V), S. Diane Germain (H), William S. Gonwa (H), Takakazu Hayashi (V), Alan Herlihy (H), Brenda L. Hockensmith (H), John P. Hogan (V), David R. Hose (GP).

Sofia Maria Kaczor (V), Ronald Kaiserman (V), Randy L. Kays (S), Elizabeth M. Kibler (V), Chang Shik Kim (O), Claude M. Laird (A), Michel J. Lebrat (V), Ling-Ling L. Leu (S), Li Li (O).

Michael E. Miller (T), Alvaro Morales (T), Amir Neori (O), Faris Nimri (H), Richard Oestrike (V), Charles H. Pardini (V), Catherine Poley (S), Fernando A. Pons (H), Donald R. Porcelli (V).

Geoffrey J. Rarick (P), Edward B. Rasteuer (H), Nestor M. Rivera (T), Barry Roberts (A), Scott E. Robinson (V), Eileen Rodriquez (O), Christine Roob (V), Victor Rossinsky (O), Samuel R. Rothermel (H), Linda Rowan (V).

Ivan I. Saavedra-Cuadra (H), Jeffrey A. Sauve (V), Keith R. Searight (GP), Robert J. Selfridge (GP), Sally N. Shake (P), Susanna E. Sichel (V), Hugh A. Smith (S), Khalil J. Spencer (V), Ralph Tango (H), Teresa Taylor (H), James L. Therrien (GP).

Emilio E. Vera (S), J. L. Wallis (T), Mary M. Washko (GP), Dale F. Woods (S), Wang-Hong Yang (V), Alexander D. Zekulin (S).

Special Rate: Color Issue of JGR-B

A special issue of the Solid Earth and Planets section of the *Journal of Geophysical Research* (JGR-B) that will feature liberal use of color at special reduced rates is being planned. The first goal is to determine the need for color graphics from authors' and readers' viewpoints. The second goal is to gain experience with economies of scale so that realistic page charges can be set.

Figures should be submitted in the final size. JGR page maximum dimensions are 17.3 cm × 24.3 cm. Both the figure and the caption must fit on the page.

Regular JGR page charges will apply for text pages. Special rates for the color pages apply to this issue only.

If press-ready color separation negatives and a color proof, such as a Cromalin, are supplied, the cost will be $170 per page of color.

If black and white prints of perfectly registered, nonscreened, solid line work where each color tone is equal density for up to four printer's colors and a color proof on the composite are supplied, the cost will be $225 per page of color.

If individual 35 mm slides of perfectly registered, nonscreened, solid line work where each color tone is of equal density for up to four printer's colors and a color proof of the composite are supplied, the cost will be $310 per page of color.

If original reflective art work that needs to be color separated by AGU is supplied, the cost will be $580 per page of color.

Submit your papers with two sets of color figures to Gerald Schubert, Department of Earth and Space Sciences, University of California, Los Angeles, Los Angeles, CA 90024 (telephone: 213-825-5665). Please be sure to identify your paper as a submission for the special color graphics issue. Normal JGR review standards apply.

For further information about supplying color for this special issue, contact the AGU Publications Office at 202-462-6903.

GAP

Separates

To Order: The order number can be found at the end of each abstract; use all digits when ordering. Only papers with order numbers are available from AGU. *Cost:* $3.50 for the first article and $1.00 for each additional article in the same order. Payment must accompany order. Deposit accounts available.

Copies of English translations of articles from Russian translation journals are available either in unedited form at the time of their listing in EOS or in final printed form when a journal is published. The charge is $2.00 per Russian page.

Send your order to:
American Geophysical Union
2000 Florida Avenue, N.W.
Washington, D.C. 20009

Aeronomy

0460 (Traveling ionospheric disturbances)
THE HEIGHT DEPENDENCE OF TID AND GRAVITY WAVE PARAMETERS
R.L. Todd, H.O. Morgan (Radiophysics Laboratory, Thayer School of Engineering, Dartmouth College, Hanover, New Hampshire, 03755), [illegible]

The height dependence of amplitude and both horizontal and vertical trace speeds, for individual spectral components of F-region TID's, are obtained for the first time by means of a three-station network of rapid-run ionosondes. The corresponding causative gravity wave parameters are derived using a previously developed inversion technique, which is extended by incorporating the effects of dissipation and ion diffusion. Reasonable agreement is achieved between the height variation of the real part of the vertical component of the gravity wave phase propagation vector, k_z, obtained from the inversion process, and solutions of a dissipative dispersion relation for k_z at different heights. Height dependent values of the imaginary part of the vertical component of the gravity wave phase propagation vector, k_{zi}, which are required for the inversion, are computed from the dissipative dispersion relation. Values of k_{zi} obtained from analytic formulae which assume an isothermal atmosphere and small dissipation, yield erroneous results for the cases considered, suggesting that care should be exercised when interpreting previous theoretical results that have employed these assumptions. (Gravity waves).
J. Geophys. Res., A, Paper 4A0801

Electromagnetics

0720 Electromagnetic Theory
THE EFFECTIVE CROSS-SECTION METHOD FOR DIELECTRIC WAVEGUIDES IN OR ON A SUBSTRATE
Edward F. Kuester (Electromagnetics Laboratory, Department of Electrical and Computer Engineering, University of Colorado, Boulder, Colorado, 80309)

It has previously been shown that the propagation constants of step-index dielectric waveguides of arbitrary cross-section and small index contrast can be computed accurately using a related metallic waveguide of a certain "effective cross-section". In this paper we extend the method to treat waveguides whose cladding is inhomogeneous, and whose refractive index is not necessarily close to that of the core (guiding region). The results are applied to dielectric waveguides embedded into or mounted upon a [illegible] substrate [illegible]. The expressions obtained are again quite simple and involve only knowledge of the [illegible] eigenvalues of a similarly-shaped metallic waveguide.
Rad. Sci., Paper 4S0822

0703 Antennas
IMPEDANCE OF VERTICAL ELECTRIC AND MAGNETIC DIPOLE ABOVE A DISSIPATIVE GROUND
E. Alanen, I. V. Lindell (Department of EE, Helsinki University of Technology, Otakaari 5 A 02150, Espoo, Finland)

Self impedance formulas for a small horizontal wire loop and for a small vertical dipole above a [illegible] are derived using the exact image principle. The resulting integrals appear extremely well behaved for low antenna elevations and give good results with the simplest numerical approximation.
Rad. Sci., Paper 4S0840

Exploration Geophysics

0920 Magnetic and electrical methods
GRAVITY AND MAGNETIC INVERSION WITH MINIMIZATION OF A SPECIFIC FUNCTIONAL
A. Guillen (Dept. Geophysique, Bureau de Recherches Geologiques et Minieres, Av. de Concyr, Orleans-La-Source BP 6009, Orleans 45060 Cedex, France) V. Menichetti

The nonuniqueness of gravity or magnetic data inversion is well known. In order to remove ambiguity, some authors have sought solutions minimizing a functional describing geometrical or physical properties. Last and Kubik (1983), in particular, developed a method explaining the observed anomaly by structures of minimum volume. In this method the domain where anomalous sources are searched is divided into elementary prisms of a constant density or susceptibility contrast. Each elementary contrast is allowed to vary individually. Thus a contrast distribution is computed.

The search for this kind of solution leads in general to geologically more appropriate bodies, but exceptions do occur. In this paper, the technique is broadened to include the search for solutions minimizing the moment of inertia with respect to the center of gravity or with respect to a given dip line passing through it. The resulting structures are both deeper and more compact, precisely as is required in specific cases. Theoretical and actual examples illustrate this flexible inversion technique.
GEOPHYSICS, VOL. 49, NO. 8

0920 Magnetic and electrical methods
RADIO-FREQUENCY GEOTOMOGRAPHY FOR REMOTELY PROBING THE INTERIORS OF OPERATING MINI- AND COMMERCIAL-SIZED OIL-SHALE RETORTS
Stephen F. Somerstein (Occidental Research Corporation, Irvine, CA 92713. Correspondence regarding this article should be sent to S.F. Somerstein, 364 Cress, Laguna Beach, CA 92651) Mike Berg, David Chang, Hwang Chung, Hal Johnson, Bill Richardson, John Pizzicara, and Winfield W. Salisbury

Cross-borehole, radio-frequency geotomographs were made across two different-sized, operating, experimental, underground, in-situ, oil-shale retorts. The tomographs taken of the smaller retort were of a plane 16.7 m wide by 18.0 m high bisecting the retort. The measurements were taken at a frequency of 25 MHz ranged from 0.40–0.45 m^{-1} across the cool, unrubbled, sill-pillar, and between 0.60–0.70 m^{-1} high-temperature 370–700°C zone. Image resolution was approximately 1 m. The signal attenuation across the lower retort region was also found to correlate well with [illegible] concentration of condensed water. The conventional algebraic deconvolution method (ART) was modified for limited perspective and finite beam width, and gave results which were in good agreement with thermocouple data.

The measurements made on the larger retort were taken over a period of 33 days of retort burn and mapped the attenuation coefficient in a vertical plane 90 m wide by 48 m high at a frequency of 1.5 MHz. At this frequency, attenuation coefficients in the cool, dry retort regions were between 0.12 and 0.15 m^{-1}. Some additional effects on the attenuation measurements were observed due to nearby thermocouple piping. [illegible] the contours of attenuation coefficient with time [illegible] temperature changes [illegible] allowed a marginal correlation to be made.

Overall results suggest that radio-frequency geotomography can be a useful tool for mapping in-situ moisture concentrations and temperature fronts in an operating in-situ oil-shale retort.
GEOPHYSICS, VOL. 49, NO. 8

0920 Magnetic and electrical methods
LOW-ALTITUDE AEROMAGNETIC RECONNAISSANCE FOR PETROLEUM IN THE ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA
Terrence J. Donovan (U.S. Geological Survey, 2255 Gemini Drive, Flagstaff, AZ 86001) John D. Hendricks, Alan A. Roberts, and Patricia Tervain Eliason

Variations in the Earth's magnetic field arising from local concentrations of shallow subsurface magnetite were mapped in the Arctic National Wildlife Refuge and elsewhere in northern Alaska. The anomalies were delineated with a magnetic horizontal gradiometer mounted on a low-flying (300 ft or 90 m above ground) fixed-wing airplane. Limited data from stable carbon isotope and [illegible] measurements of rock cores from the Cape Simpson region strongly suggest that the magnetic anomalies result from the chemical reduction of iron oxides in the presence of seeping hydrocarbons. The magnetic contrast between sedimentary rocks of normally low magnetic susceptibility and those locally enriched with this epigenetic magnetite results in distinctive high-wavenumber and low-amplitude total-field anomalies. [illegible] In a tail stinger [illegible] horizontal [illegible] path. This [illegible] of data [illegible] flight lines [illegible] generation [illegible]. Problems related to diurnal variations and solar storms at high magnetic latitudes are largely overcome because changes in total magnetic field do not significantly affect the magnetic gradient. Analysis of an experimental survey, [illegible] reveals numerous anomalies, the most prominent of which parallels the Marsh Creek anticline. The data provide further evidence that the Marsh Creek anticline is prospective for oil and/or gas. Although the effect of permafrost on epigenetic processes has not been investigated, the data suggest that special-purpose aeromagnetic surveying may be a useful and inexpensive way to explore for oil and gas in this harsh environment.
GEOPHYSICS, VOL. 49, NO. 8

0920 Magnetic and electrical methods
INDUCED POLARIZATION OF SHALY SANDS
H. J. Vinegar (Shell Development Company, Bellaire Research Center, 3737 Bellaire Blvd., Houston, TX 77001) M. H. Waxman

Equations have been developed that relate induced polarization (IP) in shaly sands to measurable petrophysical parameters. The induced-polarization process has been modeled in terms of two mechanisms: clay counterion displacement and membrane blockage. The resulting equations can be used to determine shaliness, brine conductivity, and oil saturation from in-phase and out-of-phase conductivities. Laboratory measurements have confirmed the IP dependence on these variables, as well as on temperature.
GEOPHYSICS, VOL. 49, NO. 8

0920 Magnetic and electrical methods
CROSS-HOLE MAGNETOMETRIC RESISTIVITY (MMR)
M.N. Nabighian (Newmont Exploration Ltd., 200 W. Desert Sky Road, Tucson, AZ 85704) G.L. Oppliger, R.N. Edwards, B.B.H. Lo, and S.J. Cheesman

The last decade has seen a growing acceptance of the [illegible] exploration technique in various geologic environments. Until recently, MMR exploration was carried out with both current electrodes and recording magnetometer located on the surface of the Earth. Significant improvements in anomaly amplitude can be achieved by lowering the recording magnetometer inside a drill hole. In contrast, the lowering of current electrodes beneath the surface does not always improve surface MMR responses. The advantages of locating the magnetic detector in a drill hole are illustrated numerically, anomaly calculations being carried out with a novel yet simple integral equation technique for a plate-like body. The practicality of the cross-hole MMR technique is demonstrated with a successful case history. Massive sulfide mineralization is mapped at a depth exceeding 500 m.
GEOPHYSICS, VOL. 49, NO. 8

0920 Magnetic and electrical methods
AUTOMATED INTERPRETATION OF AIRBORNE ELECTROMAGNETIC DATA
G. T. DeMoully (Formerly Engineering Geoscience, University of California, Berkeley; presently Chevron Geosciences Co., P.O. Box 42832, Houston, TX 77242) A. Becker

Recent improvements in equipment quality make it possible to increase the usefulness of airborne electromagnetic (EM) systems in areas of moderate electrical conductivity for the purpose of constructing simple electrical property maps which can be related to surficial geology. This application of airborne electromagnetics may be demonstrated and evaluated using Barringer/Questor Mark VI Input survey results in places where independent verifications of the airborne data interpretation are available.

For this purpose we have developed a set of computer algorithms which read digitally recorded input data and interpret them automatically in terms of a simple electrical section that is defined by a single conductive layer whose thickness, conductivity, and subsurface depth are determined from the data. Because this technique is formally based on a one-dimensional, three-layer, three-parameter, horizontally stratified earth model, it is only applicable in regions where the surficial formations are mildly dipping and the conductive layer is covered by, and rests on, highly resistive materials.

The interpretation method is illustrated by three field examples. At the first field survey site, in Alberta, Canada, airborne EM survey data are used to map the depth of the interface between coarse and clayey sands. Data from a second survey site, this time in the Western USA, are interpreted to yield the section of a subsurface valley filled with conductive clay. The final example, taken from British Columbia, Canada, involves the mapping of all the three parameters for a weathered volcanic unit.
GEOPHYSICS, VOL. 49, NO. 8

0930 Seismic methods
KIRCHHOFF ELASTIC WAVE MIGRATION FOR THE CASE OF NONCOINCIDENT SOURCE AND RECEIVER
John T. Kuo (Aldridge Laboratory of Applied Geophysics, Columbia University, New York, NY 10027) Ting-Fan Dai

In taking into account both compressional (P) and shear (S) waves, more geologic information can likely be extracted from the seismic data. The presence of shear and converted shear waves in both land and marine seismic data recordings calls for the development of elastic wave-migration methods. The migration method presently developed consists of simultaneous migration of P-and S-waves for offset seismic data based on the Kirchhoff-Helmholtz type integrals for elastic waves. A new principle of simultaneously migrating both P- and S-waves is introduced.

The present method, named the Kirchhoff elastic wave migration, has been tested using the 2-D synthetic surface data calculated from several elastic models of a dipping and horizontal layer, and two layers over a half-space. The results of these tests not only assure the feasibility of this migration scheme, but also demonstrate that enhanced images in the migrated sections are well formed. Moreover, the signal-to-noise ratio increases in the migrated seismic section by this elastic wave migration, as compared with that using the Kirchhoff acoustic (P-) wave migration alone. This migration scheme has about the same order of sensitivity of migration velocity variations, if V_p and V_s vary concordantly, to the recovery of the reflector as that of the Kirchhoff acoustic (P-) wave migration. In addition, the sensitivity of image quality to the perturbation of V_s/V_p has also been tested by varying either V_s or V_p. For varying V_s (with V_p fixed), the migrated images are virtually unaffected on the u_z depth section. For varying V_p (with V_s fixed), the migrated images are affected on both the u_z and u_x depth sections.
GEOPHYSICS, VOL. 49, NO. 8

Atmospheric and Oceanic Physics
Volume 19, Number 4

Chapman Conference on Vertical Crustal Motion: Measurement and Modeling

A Chapman Conference on Vertical Crustal Motion: Measurement and Modeling will be held October 22–26, 1984, in Harpers Ferry, West Virginia.

Convenor: William E. Strange

This conference will bring together scientists who measure vertical crustal motions and those who analyze and model these motions with the primary objective of obtaining close interaction between the two groups. Emphasis will be on vertical crustal movement in North America. Questions to be addressed will be (1) what are the accuracies and error sources associated with each data type? (2) What is the extent of the current data base? (3) How accurately do we know vertical crustal motions in North America? (4) What are realistic expectations of contributions from space systems and other new technologies in the next decade? (5) What is the current status of modeling vertical crustal motions? (6) How important is vertical motion information to understanding and modeling earth dynamics? (7) What are the measurement requirements to support modeling and analysis in terms of temporal and spatial density and accuracy? (8) What are the most critical deficiencies of vertical motion data relative to modeling and analysis?

There will be invited and contributed presentations. The Call for Papers was published in the March 20, 1984, issue of Eos. Abstract deadline is August 1, 1984. Abstracts should be submitted to the American Geophysical Union.

For information on the required abstract format or further meeting logistics, contact:

AGU Meeting Department
2000 Florida Avenue, N.W.
Washington, DC 20009
(202) 462-6903

For program information contact:
Dr. W. E. Strange
NOAA/NOS/CNGS/NGS/N/CG11
6001 Executive Blvd.
Rockville, MD 20852
(301) 443-2520

0930 Seismic methods
OFFSET PANEL
Thomas F. Fulton (Gulf Oil Exploration and Production Co., P.O. Box 61590, New Orleans, LA 70161) K. Michele Darr
The offset panel is a display of basic seismic data which combines single-channel profiles from successive offsets (source-to-receiver distances) into one format. The profiles are displayed one below another and arranged vertically by offset and horizontally by common-depth-point. This arrangement allows for comparison of variations observed at one offset to those at another offset. Alteration of the data due to near-surface geologic variations generates geometric patterns on the display which are different from patterns due to changes in seismic source or receiver. This display has utility in data processing to verify field recording geometry, monitor the seismic source (primarily a marine application), and determine processing parameters. It aids data interpretation by allowing for the detection of an anomalous velocity zone in the near-surface which may affect deeper structural interpretation. Utilization of the offset panel in identification of shallow events of high amplitude also allows identification of shallow drilling hazards in the marine environment with conventional seismic data.
GEOPHYSICS, VOL. 49, NO. 8

0930 Seismic methods
A METHOD FOR COMPUTATION OF VELOCITY PROFILES BY INVERSION OF LARGE-OFFSET RECORDS
Philip M. Carrion (Aldridge Laboratory of Applied Geophysics, Henry Krumb School of Mines, Columbia University, New York, NY 10027) John T. Kuo
This paper describes a new method for recovering velocity profiles utilizing both phase and amplitude information including wide-angle arrivals, post- and pre-critical reflections.
This method is based on a double spatial transformation with a minimization procedure. The first transformation is slant stacking of the observed wave field (seismogram). The second is projecting the slant stacked wave field into the domain of horizontal slowness p and depth z. In this domain the inverse problem is reduced to finding the critical path $p=V^{-1}(z)$ where $V(z)$ is the true velocity of the compressional waves. A numerical algorithm based on a minimization technique is used to find the critical path, which is equivalent to the set of turning points of the critically reflected rays. When this path is found, then the following criteria are satisfied:
(1) Most of the energy is concentrated away from the precritical region;
(2) the computed reflection coefficients reach their maxima on this path; and
(3) for horizontally stratified media or CMP data, the reflectors are aligned in the p-z domain.
In tests, this method has been shown to recover the velocity profile from both synthetic and real data. It is shown that the method is able to recover accurately velocity profiles even if only part of the data are given. For example, only part of the data are available when low- and high-frequency components are missing or when the data are truncated in lateral extent due to the finite length of the recording system. Moreover, the method is able to handle virtually any vertical velocity gradients in a medium; therefore, it can be applied to complicated geologic structures. The method does not require elimination of multiples, but it is not applicable to the case of a medium with a large lateral velocity gradient. It can be used even for an elastic medium when the mode-converted energy is not small.
GEOPHYSICS, VOL. 49, NO. 8

0930 Seismic methods
ROCK LITHOLOGY AND POROSITY DETERMINATION FROM SHEAR AND COMPRESSIONAL WAVE VELOCITY
S. N. Domenico (ROBSHIR Consultants, Inc., 4685 S. Maplewood Avenue, Tulsa, OK 74135)
Data examined in this study are previously published laboratory shear (S) and compressional (P) wave velocity measurements on water-saturated sandstone, calcareous sandstone, dolomite, and limestone cores, as well as laboratory porosity measurements on the sandstone and limestone cores. Sandstone and limestone porosities range from .092 to .299 and from .006 to .379, respectively. Differential pressure was varied from 500 to 6000 psi, corresponding to approximate burial depths from 290 to 3560 m, respectively.
Sandstone, limestone, and dolomite are effectively separated by Poisson's ratio σ or, equivalently, by the ratio of P- to S-wave velocity. Separation of sandstone and limestone appears to result from the difference in σ of the matrix material, namely, quartz (.056) and calcite (.316), respectively.
An empirical function, $1/V = A + B\phi$, was fit by regression analysis to sandstone and limestone velocity (V_p and V_s) versus porosity (φ) values at each differential pressure. In this equation A and B are constants at each pressure, A being approximately equal to the reciprocal matrix velocity. Decreasing standard deviation indicates that the equation becomes an appreciably more accurate representation of the measured data as pressure increases. Average values of A are near reciprocal velocities of quartz (sandstone averages) and calcite (limestone averages). The constant B, rate of change of reciprocal with porosity, is a critical measure of the sensitivity of velocity to porosity, hence the usefulness of velocity in estimation of porosity. Sandstone S-wave B values are from 2 to 5 times greater than all other values, indicating that sandstone S-wave velocity is by far the most sensitive to porosity variation. Least sensitive is limestone P-wave velocity.
GEOPHYSICS, VOL. 49, NO. 8

0930 Seismic methods
KIRCHHOFF INTERGRAL EXTRAPOLATION AND MIGRATION OF NONPLANAR DATA
J. W. Wiggins (Gulf Research and Development Co., P.O. Box 37048, Houston, TX 77236)
The form of the Kirchhoff integral commonly used for migration of seismic data assumes that the observation surface is a flat, horizontal plane. A useful integral expression can be obtained for an arbitrary observation surface by use of the Kirchhoff approximation for relating the field on the observation surface to its normal derivative. Kirchhoff migration is usually carried out by an intergral that represents summation over receivers for a given shot. Summation over shots is not explicitly handled. By invoking the principle of reciprocity and applying the Kirchhoff intergral twice, one arrives at an integral expression that explicitly represents shot and receiver summation, contains the factors needed to compensate for nonplanar survey geometry, and can be used for wave extrapolation as well as migration. Adaptation of this integral to handling 2-D or line survey data is straightforward and, with the usual approximations concerning spherical wave spreading, it accomplishes 2-D wave extrapolation and migration.
By tabulating both average and rms velocity functions, the Kirchhoff integral can be used to handle cases where the velocity changes vertically and the survey surface has vertical relief. The approximations involved are only those usually required in calculations of rms velocity traveltime. Migration is illustrated by treatment of two model data sets. One data set has shots and receivers extended horizontally with the receiver path undergoing strong elevation changes and the shot path flat. Migration of these data illustrates the effect of the geometrical weighting factors and the effectiveness of the rms velocity approximation. The second data set is a vertical seismic profile (VSP) with shots extended horizontally and receivers extended vertically down a single well. Migration of these VSP data yields a useful image for a reasonable distance away from the well. Migration of nonplanar survey data is quite practical with geometrical artifacts that are manageable. The technique has use for surveys taken over nonplanar topography, for imaging from VSP data, and in a dual role for treatment of velocity anomalies, i.e., first as a wave extrapolation procedure to move below the anomaly and then as a migration procedure applied to the nonplanar extrapolated data.
GEOPHYSICS, VOL. 49, NO. 8

0930 Seismic methods
INVERSION OF SEISMIC REFLECTION DATA IN THE ACOUSTIC APPROXIMATION
Albert Tarantola (Laboratoire de Sismologie (LA CNRS 195), Institut de Physique du Globe de Paris, Univ. P. et M. Curie, 4 Place Jussieu, 75230, Paris Cedex 05, France)
The nonlinear inverse problem for seismic reflection data is solved in the acoustic approximation. The method is based on the generalized least-squares criterion, and it can handle errors in the data set and a priori information on the model. Multiply reflected energy is naturally taken into account, as well as refracted energy or surface waves. The inverse problem can be solved using an iterative algorithm which gives, at each iteration, updated values of bulk modulus, density, and time source function. Each step of the iterative algorithm essentially consists of a forward propagation of the actual sources in the current model and a forward propagation (backward in time) of the data residuals. The correlation at each point of the space of the two fields thus obtained yields the corrections of the bulk modulus and density models. This shows, in particular, that the general solution of the inverse problem can be attained by methods strongly related to the methods of migration of unstacked data, and commercially competitive with them.
GEOPHYSICS, VOL. 49, NO. 8

0930 Seismic methods
ESTIMATION OF STATIC CORRECTIONS FOR SHEAR-WAVE PROFILING USING THE DISPERSION PROPERTIES OF LOVE WAVES
J. L. Mari (Institut Français du Petrole, 1 and 4 Av. de Bois Preau, 92502 Rueil-Malmaison, France)
When processing shear-wave data, it is often difficult to compute the static corrections using the same methods as for P-waves, because of the low velocities involved and of interference with residual P-waves.
A method especially tailored for static corrections of SH-waves is presented, which makes use of the dispersion property of Love waves. Assuming that the weathered zone of thickness H acts as a waveguide for the surface waves, their phase velocity ranges from V_1 at infinite frequency to V_2 at zero frequency, where V_1 and V_2 are the shear-wave velocities into and below the weathered zone. For intermediate frequencies the phase velocity of Love waves is a known function of H, V_1, and V_2. If the phase velocity of Love waves is measured on field records for a number of distinct frequencies, it is therefore possible to compute H, V_1, V_2, and the static corrections.
In contrast with conventional techniques which require first arrivals to be picked manually, the computation of static corrections using the dispersion of Love waves is essentially based on velocity analysis efficiently performed by digital computers.
Three field examples were conducted. The first of these was a noise analysis using 256 geophone positions ranging from 3 to 258 m. The two other examples are CDP lines obtained with polarized SH sources. The geophone group extension is 20 m and the distance between groups is 10 m. In all these examples, the upper layer thickness and velocity values resulting from the Love wave dispersion appeared to be in good agreement with those computed from the conventional methods.
GEOPHYSICS, VOL. 49, NO. 8

0930 Seismic methods
THE RADON TRANSFORM AND ITS PROPERTIES
T. S. Durrani (Dept. of Electronic and Electrical Engineering, University of Strathclyde, 204 George Street, Glasgow G1 1XW, United Kingdom) D. Bisset
This paper presents a summary of the fundamental properties of the Radon transform, including delay effects, data shifting, rotation, scaling windowing, boxcar events, energy, energy conservation, etc., and includes representative examples on standard data sets such as 2-D delta functions, boxcar events, Gaussian bell, and conic sections which reinforce the basic concepts of the Radon transform.
GEOPHYSICS, VOL. 49, NO. 8

0930 Seismic methods
SEISMIC VERSUS SONIC VELOCITIES: A VERTICAL SEISMIC PROFILING STUDY
Robert R. Stewart (Formerly ARCO Oil and Gas Co., Dallas; presently Chevron Geosciences Company, 500-5th Ave. S.W., Calgary, Alta., Canada T2P 0L7) Phil D. Huddleston and Tze Kong Kan
Vertical seismic profiling (VSP) techniques provide a method to measure accurately the seismic velocity and lithologic structure near the borehole. The analysis of a VSP survey can also provide insight into seismic-wave propagation especially when related to sonic measurements.
But VSP and sonic log velocities (or traveltimes) are often found to disagree. Recent field evidence of these differences suggests that the VSP traveltimes are delayed with respect to the intergrated sonic times, especially in the deep section (>3000 ft), by about 2.0 ms/1000 ft on the average. The VSP has numerous applications in exploration geophysics, such as calibrating the sonic log. It is thus important to understand why the two measurements differ.
Differences in the geometries, source frequencies, and instrumental errors of the two surveys are reviewed. More detailed analysis of seismic wave propagation in the VSP shows that short-path multiples and velocity dispersion can have a significant delaying effect on the seismic traveltimes. One-dimensional, wide-band VSP synthetic seismograms are generated in the frequency domain to study these effects. Different parameters (bandwith, signal-to-noise, layer thickness, multiples, attenuation, dispersion) are varied in the synthetic seismograms. A comparative display of synthetic VSP traveltime minus the integrated sonic time is used to view the effects of those parameters on the synthetic traces. Reasonable variations in noise, layer thickness, bandwidth, and picking method have a small effect on traveltimes. Field data from the Anadarko Basin (4 wells) and an East Texas well are examined with the same technique. From the modeling and field examples, it is found that short-path multiples can cause a seismic pulse delay of up to 2.0 ms/1000 ft with respect to the integrated sonic log in highly cyclically stratified sections. Velocity dispersion associated with attenuation can have a larger effect, causing up to 7.0 ms/1000 ft delay of the VSP traveltimes with respect to the integrated sonic. These wave propagation effects can explain the observed discrepancy between VSP and integrated sonic time in the deep section.
GEOPHYSICS, VOL. 49, NO. 8

0930 Seismic methods
SEISMIC INDICATORS OF STRATIGRAPHY
A. Sinvhal (Formerly University of Roorkee, Roorkee, India; presently Biostatics Unit, Medical Research Council, Hills Road, Cambridge, UK) F. H. Khattri, H. Sinvhal, A. K. Awasthi
An attempt has been made to predict relative contents of sand, shale, and coal in a sequence of lithologies as traversed and depicted by a seismogram, using discriminant analysis. Monte Carlo simulations and Markov chains have been used to model the subsurface, and discriminant analysis was first tried on these and then tested on field data. Subsurface lithology was predicted by this technique and shows great potential in future exploration programs.
GEOPHYSICS, VOL. 49, NO. 8

Geochemistry

1490 Techniques (Ground Water Geochemistry)
A BOREHOLE METHODOLOGY FOR HYDROGEOCHEMICAL INVESTIGATIONS IN FRACTURED ROCK
D.J. Bottomley (National Hydrology Research Institute, Environment Canada, 562 Booth St., Ottawa, Ont. K1A 0E7) J.D. Ross and B.W. Graham
Research into the development of borehole techniques for hydrogeochemical investigations in fractured rock has resulted in the construction of a geochemical probe controlled and operated with an umbilical cable system. This probe has been field tested to a depth of 600 m in a multi-level ported casing at the Chalk River Nuclear Laboratories (CRNL). The probe provides in situ measurements of pH, redox potential, dissolved oxygen, temperature, conductivity, and pressure while allowing ground water sample collection both at surface and downhole. The multi-level ported casing preserves the subsurface hydrogeochemical zonation and facilitates sampling at various depths. In the CRNL borehole dilute Na/HCO_3 and Na/Cl waters ranging in age from 500 to 12000 years have been observed in gneissic rock at depths of 85 to 350 m. However, accurate hydrogeochemical characterization of the low permeability metagabbro present from 400 to 600 m has been frustrated by contamination from casing installation water. (Geochemistry, ground water, fractured rock).
Water Resour. Res., Paper 4W0729

Geodesy and Gravity

1910 Crustal Movements
DEFORMATION IN THE WHITE MOUNTAIN SEISMIC GAP, CALIFORNIA-NEVADA, 1972-1982
J.C. Savage (U.S. Geological Survey, 345 Middlefield Road, Menlo Park, California 94025) and M. Lisowski
A 100 km by 40 km trilateration network extending from Bishop, CA, to near Hawthorne, NV, crosses the east end of the Long Valley caldera, site of renewed magma inflation in the 1979-80 interval, and spans most of the White Mountain seismic gap. The network was surveyed in 1972, 1973, 1976, 1979, 1980, and 1982. The 1980 survey may be contaminated by a scale error. In addition, leveling surveys across the caldera have been run in 1932, 1957, 1975, 1980, 1982, and 1983. Interpretation of the deformation is complicated by the occurrence of the May, 1980, Mammoth Lakes earthquake sequence (four earthquakes $M_L \geq 6$) at the south edge of the caldera as well as other moderate earthquakes within the White Mountain seismic gap. The vertical deformation is largely accounted for by 0.10 to 0.15 km^3 expansion of a spherical magma chamber 8 to 10 km beneath the resurgent dome within the Long Valley caldera sometime between July 1979 and September 1980 with an additional expansion of perhaps 0.05 km^3 between September 1980 and July 1982. Some additional sources of deformation within the aftershock zone of the Mammoth Lakes earthquakes seem to be required to explain the horizontal deformation. We show that right-lateral slip on vertical faults extending WNW from each of the three largest earthquakes in the Mammoth Lakes sequence provides the required additional deformation, but this solution is by no means unique. There are simply too few data to define the rather complex deformation that apparently occurred within the aftershock zone. There is little doubt, however, that inflation of a magma chamber beneath the resurgent dome within the Long Valley caldera was involved in the deformation. (Long Valley caldera, Mammoth Lakes earthquakes.)
J. Geophys. Res., B, Paper 4B0780

Geomagnetism and Paleomagnetism

2560 Time Variations (Reversals)
TRANSITIONAL PALEOINTENSITIES FROM KAUAI, HAWAII, AND GEOMAGNETIC REVERSAL MODELS
S. W. Bogue (Department of Geological Sciences AJ-20, University of Washington, Seattle, Washington, 98195) and R. S. Coe
Thellier paleointensity results from an R-N transition zone in Kauai, Hawaii, show that field intensity dropped from 0.431 Oe to 0.101 Oe while the field remained within 30° of the reversed axial dipole direction. A recovery in intensity and the main directional change followed this presumably short period of low field strength. As the reversal neared completion, the field had an intensity of 0.217 Oe while still 40° from the final direction. The relationship of paleointensity to field direction during the early part of the reversal thus differs from that towards the end, a feature that only some reversal models are consistent with. For example, a model in which a standing nondipole component persists through the dipole reversal predicts only symmetric intensity patterns. In contrast, zonal flooding models generate suitably complex field behavior if multiple flooding schemes operate during a single reversal or if the flooding process is itself asymmetric. (Transition zones, paleointensity, reversal models, Kauai).
J. Geophys. Res., B, Paper 4B0806

Hydrology

3125 Glaciology
A TWO-PHASE MODEL OF ELECTRICAL CONDUCTION IN POLAR ICE SHEETS
E.W. Wolff (British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge CB3 0ET, UK), and J.G. Paren
It has been suggested that the D.C. conductivity of polar ice sheets could be due to the presence of liquid layers at the grain boundaries. These layers would consist of a mixture of acids with water. We show that it is plausible that acids will be at three-grain boundaries in polar ice. Using reliable data for H_2SO_4, HNO_3 and HCl concentrations in ice at South Pole, we derive the correct magnitude and temperature dependence for its conductivity. The model explains the narrow range of ice conductivities found in polar regions. (Ice, electrical conduction, grain boundaries, acids).
J. Geophys. Res., B, Paper 4B0835

3130 Groundwater
THREE-DIMENSIONAL STREAMLINES IN DUPUIT-FORCHHEIMER MODELS
O. D. L. Strack (Department of Civil and Mineral Engineering, University of Minnesota, Minneapolis, MN, 55455).
Equations are presented for determining flow paths in three dimensions using Dupuit-Forchheimer solutions to groundwater flow problems. The equations are derived by applying the condition of continuity of flow, interpreting the Dupuit-Forchheimer approximation as neglecting the resistance to flow in the vertical direction. The approximation is compared with exact solutions for several cases of steady flow; it appears that the deviations increase with increasing spatial variation of the source term in the differential equation. As an example, the technique is applied to a case of leakage through the bottom of a circular pond in a field of uniform flow in an unconfined aquifer. The approach will make it possible to trace particles through the various layers in multi-layer aquifer models. (Streamlines, flow path, modeling).
Water Resour. Res., Paper 4W0384

3130 Groundwater
LINEARIZATION TECHNIQUES AND SURFACE OPERATORS IN THE THEORY OF UNCONFINED AQUIFERS
G. Bodvarsson (College of Oceanography, Oregon State University, Corvallis, Oregon, 97331)
The non-linear pressure boundary condition at the free liquid surface in unconfined aquifers can be linearized such that standard methods can be applied to solve the pressure equations. Defining a new type of cross-surface differential operators, the linearized free surface condition can be interpreted as a new type of partial differential equation in the boundary surface. As examples of the techniques introduced, solutions for the impulse response of the unconfined half-space and for an unconfined box-type domain are presented. (Linearized, unconfined, boundary operators).
Water Resour. Res., Paper 4W0815

Physics of the Solid Earth
Volume 19, Number 5

3130 GROUNDWATER
THE EFFECT OF TORTUOSITY ON FLUID FLOW THROUGH A SINGLE FRACTURE
Y. W. Tsang (Earth Sciences Division, Lawrence Berkeley Laboratory, University of California, Berkeley, California, 94720)
Calculations to investigate the effect of path tortuosity and connectivity on fluid flow rate through a single rough fracture were carried out. The flow paths are represented by electrical resistors placed on a two-dimensional grid, the resistances vary as the inverse of the fracture aperture cubed. The electric current through the circuit bears a one-to-one correspondence to the fluid flow rate. Both fracture apertures derived from measurements and from hypothetical analytic functions were used in a parameter study to investigate the dependence of tortuosity on fracture roughness characteristics. It was found that the more small apertures there are in the aperture distribution, the larger is the effect of tortuosity. When the fraction of contact area between the fracture surfaces rises above 30%, the aperture distributions are invariably large at small apertures, and the effect of fracture roughness and flow path tortuosity depresses flow rate from the value predicted by the parallel plate representation of a fracture by three or more orders of magnitude. The impact of these results on the calculations and measurements in fracture hydrology was discussed. (Fracture, flow tortuosity).
Water Resour. Res., Paper 4W0827

3130 Groundwater
INTERPRETATION OF DOWNHOLE DATA AND DEVELOPMENT OF A CONCEPTUAL MODEL FOR THE REDONDO CREEK AREA OF THE BACA GEOTHERMAL FIELD
M. A. Grant, S. K. Garg (S-CUBED, P.O. Box 1620, La Jolla, California, 92038), T. D. Riney
Drilling records, downhole pressure and temperature surveys, and surface discharge measurements available from the Redondo Creek Area wells are analyzed to define the thermodynamic state of the reservoir fluid and to determine the locations of permeable horizons. The reservoir fluid contains a significant amount of carbon-dioxide. A two-phase region is present within the reservoir; the extent of this region is profoundly influenced by the carbon-dioxide content of reservoir fluid. Two permeable zones are delineated, i.e. one within the Bandelier Tuff and one near the interface between the Bandelier Tuff and the underlying Paliza Canyon Andesite. This paper also presents a conceptual model of the Baca geothermal field. Baca is a high temperature liquid-dominated field of moderate to low permeability. It is suggested that the reservoir is charged by hot upwelling fluids at a point near Sulfur Creek. These fluids flow laterally towards Redondo Creek, and thence to ultimate outflow down the Jemez River Valley. (Geothermal Reservoirs, Baca Field, Conceptual Reservoir models).
Water Resour. Res., Paper 4W0825

3150 Precipitation (Hydrology)
A SPECTRAL THEORY OF RAINFALL INTENSITY AT THE MESO-β SCALE
E. Waymire, V. K. Gupta (Department of Civil Engineering, University of Mississippi, University, Mississippi 38677), I. Rodriguez-Iturbe
The available empirical descriptions of extratropical cyclonic storms are employed to formulate a physically realistic stochastic representation of the ground level rainfall intensity field in space and time. The stochastic representation is based on three component stochastic point processes which possess the general features of the embedding of raincells within small mesoscale areas within large mesoscale areas within synoptic storms. Certain scale idealizations, and assumptions on functional forms which qualitatively reflect the physical features, lead to a closed form expression for the covariance function, i.e., the real space-time spectrum, of the rainfall intensity field. The theoretical spectrum explains the empirical spectral features observed by Zawadzki almost a decade ago. Of particular interest and importance in this connection is an explanation of the empirical observation that the Taylorian propogation of the fine scale structure, via a transformation of time to space through the storm velocity, holds only for a small time lag and not throughout. The results here indicate the extent of this lag in terms of the characteristic scales associated with cell durations, cellular birthrates and velocities, etc. (Mesoscale, precipitation, turbulence, stochastic).
Water Resour. Res., Paper 4W0839

3160 Runoff and Streamflow
FORECASTING WATER LEVELS FOR LAKE CHAD
K. Guganesharajah (Sir M. MacDonald & Partners, Demeter House, Station Road, Cambridge, CB1 2RS, UK) and E. M. Shaw
The discharge measurements of the River Chari at N'Djamena and lake levels at Bol have been used to derive models to forecast minimum water levels of Lake Chad. First, an autoregressive model is obtained to calculate the change in minimum lake level from one year to the next, given the Chari discharge and the minimum lake depth in the previous year. A more rigorous analysis of the data produces forecasting models on a probabilistic basis to measure the risk in selecting various abstraction levels of water. The probabilistic models assume (a) the data are purely random, (b) the discharge series contains cyclical as well as stochastic components. Dividing the range of lake levels into 12 designated states, probability matrices are derived for state transitions for a single year ahead and for n-steps ahead. The expected success of n-step ahead forecasts is obtained. Diagrams showing the probability of exceedance of minimum lake level states using the random and mixed process models are presented. (Lake Chad, Chari River, water levels, probabilistic models.)
Water Resour. Res., Paper 4W0472

3190 Instruments and Techniques (Mixture Distributions)
MAXIMUM LIKELIHOOD ESTIMATES FOR THE PARAMETERS OF MIXTURE DISTRIBUTIONS
K.M. Leytham (9538 44th Ave. N.E., Seattle, WA 98115)
Maximum likelihood estimates for the parameters of a mixture of two normal distributions are presented in terms of an expectation-maximization algorithm. Small sample properties of both parameter and quantile estimates are explored using Monte Carlo simulation. Although parameters estimated from unclassified data are inaccurate, quantiles estimated from unclassified data are found to be only slightly less accurate than quantiles estimated from classified data.
Water Resour. Res., 4W0554

Journal of Geophysical Research

Volume 89 Number D4 June 30, 1984

NIMBUS 7 Scientific Results

Physics of the Solid Earth
Volume 19, Number 6

3199 General
A MIN-MAX APPROACH TO RESERVOIR MANAGEMENT
S. Orlovski, S. Rinaldi (Centro Teoria dei Sistemi, Politecnico di Milano, Milano, Italy 120133), R. Soncini-Sessa.
A deterministic (min-max) approach to real time operation of a multipurpose reservoir is presented in this paper. The use of this method is particularly justified when the attention and effort of the manager are mainly focused on avoiding substantial failures of the system during severe hydrological episodes (risk-averse attitude). The approach does not require complex algorithms and on-line optimization, since all efficient operating rules can simply be obtained by off-line repetitive simulations of the reservoir behaviour for different values of the initial storage (the selection of these values is guided by a one-dimensional searching method). These efficient operating rules can be interpreted in terms of storage allocation zones which are not predetermined but depend upon the forecast of the inflows. Moreover, when the reservoir is not too full or too empty the method suggests a whole range of possible releases, instead of a single value, thus introducing some flexibility into the decision-making process. The analysis of a real case has also shown that this deterministic approach is quite powerfull in pointing out the possibility of improving the performance of a reservoir already in operation. (reservoir management, optimal control).
Water Resour. Res., Paper 4W0845

Meteorology

3715 Chemical composition and chemical interactions
AN ANALYSIS OF THE ANNUAL CYCLE IN UPPER STRATOSPHERIC OZONE
J. E. Frederick (Atmospheric Chemistry Branch, Code 964, NASA/Goddard Space Flight Center, Greenbelt, Maryland, 20771), G. N. Serafino and A. R. Douglass
The mid-latitude upper stratospheric ozone profiles obtained by the Solar Backscatter Ultraviolet (SBUV) instrument on the Nimbus 7 satellite show a clear annual cycle both in the absolute ozone amounts between 0.98 and 15.6 mb and in the magnitude of disturbances which reveal themselves as longitudinal structure. At the lowest pressures analyzed a winter maximum in ozone exists, but as one progresses downward in altitude a shift in the temporal phase of the annual cycle occurs in the vicinity of 3 to 4 mb. Comparison of the observed behavior with the predictions of a one-dimensional photochemical model shows a systematic tendency for calculated ozone amounts to be 20-27% below the data for pressures less than 7.6 mb. The chemical model successfully predicts the change in phase of the annual cycle, although at a pressure greater than observed. Diagnosis of model results shows the observed shift to be closely coupled to the magnitude of the ozone column density near 3-4 mb. The wavelength dependent attenuation of the solar radiation field by ozone alters the relative magnitude of the molecular oxygen and ozone dissociation rates, leading to a change in the temporal phase of the annual cycle.
J. Geophys. Res., D, Paper 4D0850

3720 Climatology
CLOUD OPTICAL THICKNESS FEEDBACKS IN THE CO_2 CLIMATE PROBLEM
R. C. J. Somerville (Scripps Institution of Oceanography, Climate Research Group, A-024, La Jolla, CA 92093), L. A. Remer
A radiative-convective equilibrium model is developed and applied to study cloud optical thickness feedbacks in the CO_2 climate problem. The basic hypothesis is that in the warmer and moister CO_2-rich atmosphere, cloud liquid water content will generally be larger too. For clouds other than thin cirrus, the result is to increase the albedo more than to increase the greenhouse effect. Thus the sign of the feedback is negative: cloud optical properties act as a thermostat and alter in such a way as to reduce the surface and tropospheric warming caused by the addition of CO_2. This negative feedback can be substantial. When observational estimates of the temperature dependence of cloud liquid water content are employed in the model, the surface temperature change due to doubling CO_2 is reduced by about one half. This result is obtained for global and annual average conditions, no change in cloud amount or altitude, and constant relative humidity. These idealizations, together with other simplifications typical of one-dimensional radiative-convective climate models, render the result tentative. Further study of cloud optical property feedbacks is warranted, however, because the climate is apparently so sensitive to them. (Cloud feedbacks, climate models).
J. Geophys. Res., D, Paper 4D0814

3799 General (Radiation Budget)
LONGWAVE RADIATION BALANCE UNDER A STRONG SURFACE INVERSION IN THE KATABATIC WIND ZONE, ANTARCTICA
T. Yamanouchi and S. Kawaguchi (National Institute of Polar Research, Itabashi-ku, Tokyo, 173 Japan)
Measurements and calculations of longwave radiation fluxes were made under the Japanese POLEX program, 1979-81, at Mizuho Station (70°42'S, 44°20'E), where the katabatic wind was blowing continuously and a strong surface inversion existed. Downward and upward longwave fluxes were measured directly using pyrgeometers with a shading ring. Numerical calculations were made using a wide band model. The affect of clouds is large; overcast skies give an increase of about 80 W/m^2 in the downward flux in all seasons. The small amount of column water vapor yields the effective emissivity of the atmosphere small. The drifting snow increases the downward longwave flux and suppresses the longwave cooling at the surface. A linear relation between the strength of the surface inversion and net longwave flux is shown. (Radiation, surface inversion, Antarctica).
J. Geophys. Res., D, Paper 4D0851

Mineralogy, Petrology, and Crystal Chemistry

4260 Petrogenesis
GEOTECTONIC SIGNIFICANCE OF GNEISSIC AMPHIBOLITES FROM THE VEMA FRACTURE ZONE, EQUATORIAL MID-ATLANTIC RIDGE
J. Honnorez (RSMAS, University of Miami, Miami, FL 33149), C. Mevel and R. Montigny.
Gneissic amphibolites, serpentinites and metagabbros were recovered by 2 dredge-hauls from the foot of the north facing slope of the transverse ridge forming the south wall of the Vema Fracture Zone. The amphibolites were probably derived from various types of gabbroic rocks which completely recrystallized under stress in the conditions of the amphibolite facies (between 550° and 650°C). The amphibolites were affected by a very slight and restricted retrograde metamorphism, possibly when the transverse ridge was uplifted to higher levels of the oceanic crust. The associated metagabbros display secondary mineral parageneses indicating more complex cooling and deformation histories but did not reach metamorphic equilibrium. Whole cataclastic and paragenetic ranges were observed between gabbros and amphibolites. It is tentatively concluded that the gneissic amphibolites formed as a result of intense hydrothermal reactions between Layer 3 gabbros and seawater derived solutions. K/Ar dating suggests that the amphibolite facies metamorphism occurred about 10 My ago, i.e., when the dredging sites on the southern wall were located in the vicinity of the Mid-Atlantic Ridge. Hydrothermal circulation of seawater along the highly fractured southern wall of the fracture zone was activated by emplacement of basaltic magmas at the spreading center. (Amphibolites, fracture zones, hydrothermal metamorphism).
J. Geophys. Res., B, Paper 4B0776

Oceanography

4705 Boundary Layer and exchange processes
DUAL RADIOTRACER MEASUREMENT OF ZOOBENTHOS-MEDIATED SOLUTE AND PARTICLE TRANSPORT IN FRESHWATER SEDIMENTS
J.R. Krezoski (Center for Great Lakes Studies, University of Wisconsin-Milwaukee, Milwaukee, WI 53201), J.A. Robbins and D.S. White
Gamma spectroscopy methods were used to determine the effects of two freshwater benthic macroinvertebrates, Stylodrilus heringianus (oligochaete worms) and Pontoporeia hoyi (crustacean amphipods), on the reworking of sediments and the transfer of solutes across the sediment-water interface. In laboratory microcosms submillimeter layers of ^{137}Cs labeled solids were deposited on the sediment surface while overlying water was spiked with ^{22}Na.
In cells with Stylodrilus, the ^{137}Cs layer moved downward at an exponentially decreasing rate. The displacement of the layer results from the conveyor-belt feeding mode of this organism. The rate of marked layer burial is consistent with that of other freshwater annelids (1.8 × 10^{-6} cm day^{-1} individual^{-1} m^{-2}; 11.6°C). The exponential decrease in burial rate is ascribed to uniformly distributed feeding of Stylodrilus within the feeding zone of 4.4 cm. In cells with Pontoporeia, ^{137}Cs activity was smeared downward in time owing to eddy diffusive mixing of sediments over a small range (1-2 cm).
In cells without worms, the Cs active material remained at the interface while the ^{22}Na penetration into sediments was consistent with diffusion in free solution with small corrections for sediment porosity and sorption (K_D = 0.17). The effective diffusion coefficient for ^{22}Na (8.2 × 10^{-6} cm^2 sec^{-1}) was essentially the same as that for a cell which had been inhabited by worms for three weeks and then poisoned with formalin just before addition of ^{22}Na. Thus, the presence of biogenically reworked sediments (with pelletized materials and remnant burrow structures) did not affect solute transport. In cells with live Stylodrilus, penetration of ^{22}Na within the feeding zone was considerably more rapid, implying an apparent D_e twice as high as in cells without worms. Particle reworking results were used to develop a transport model which includes advective as well as diffusive terms. Advective transport arises from the incorporation of ^{22}Na into pore fluids moved downward as a result of conveyor-belt feeding. Within the feeding zone, solute transport is dominated by advection and the apparent enhancement of D_e in pure diffusion models is really the result of solute flow induced by particle reworking. In cells with Pontoporeia D_e is approximately twice that in control cells. In these cells ^{22}Na profiles may be treated theoretically without advection. (Bioturbation)
J. Geophys. Res., B, Paper 4B0435

4770 Turbulence and diffusion
THE ROTARY BOTTOM BOUNDARY LAYER
D. W. Ostendorf (Civil Engineering Department, University of Massachusetts, Amherst, MA, 01003)
We derive a simple analytical model of the boundary layer induced by rotary tidal currents flowing over a horizontal bottom in the absence of strong vertical stratification, formulating explicit estimates of the shear velocity, dissipation, and friction factors relating inviscid velocity to bottom shear stress. These friction factors may accordingly be calibrated by an observed velocity profile through the rotary bottom boundary layer, thereby reducing the empiricism of existing depth averaged models of tidal hydraulics. We illustrate the procedure by analyzing measured M2 rotary current profiles on the outer European shelf with good model accuracy; the local dissipation-based friction factor compares favorably with a global value based upon a calibrated numerical model of the north-west European shelf as well. (Boundary layers, bottom friction, tidal currents).
J. Geophys. Res., C, Paper 4C0836

Particles and Fields—Interplanetary Space

5380 Solar Wind Plasma
COLLECTIVE CAPTURE OF RELEASED LITHIUM IONS IN THE SOLAR WIND
D. Winske (Los Alamos National Laboratory, Los Alamos, NM, 87545), C. S. Wu, Y. Y. Li and G. C. Zhou
The capture of newly ionized lithium ions in the solar wind by means of electromagnetic instabilities is investigated through linear analysis and computer simulation. Three instabilities, driven by a lithium velocity ring that is perpendicular to and drifting parallel along the magnetic field, are considered. The capture time of the lithium by the solar wind is roughly ten linear growth times, regardless of whether resonant or nonresonant modes dominate initially. Possible implications of the results for the AMPTE mission are discussed. (Plasma instabilities, solar wind).
J. Geophys. Res., A, Paper 4A0803

Oceanology
Volume 23, Number 3

Particles and Fields—Ionosphere

[illegible]

Particles and Fields—Magnetosphere

[illegible]

Physical Properties of Rocks

[illegible]

Planetology

[illegible]

Tectonophysics

[illegible]

Volcanology

[illegible]

Oceanology
Volume 23, Number 4